FINAL REPORT
GEOTECHNICAL INVESTIGATION
ROUTE SELECTION STUDY
RICHMOND TRANSPORT SEWER
SAN FRANCISCO, CALIFORNIA
FOR THE CITY AND COUNTY OF
SAN FRANCISCO.

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FINAL REPORT
GEOTECHNICAL INVESTIGATION

MARCH, 1979

# ROUTE SELECTION STUDY
# RICHMOND TRANSPORT SEWER
## SAN FRANCISCO, CALIFORNIA

FOR THE CITY & COUNTY OF SAN FRANCISCO

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March 9, 1979

City and County of San Francisco
Department of Public Works
359 City Hall
San Francisco, California 94102

Attention: Mr. Donald J. Birrer, City Engineer

Gentlemen:

We are pleased to transmit ten copies of our report, "Geotechnical Investigation, Route Selection Study, Richmond Transport Sewer, San Francisco, California." The study was performed in accordance with the Department of Public Works Order Number DPW110029.

The accompanying report presents the results of our study for selection of alternative routes for the proposed sewer, and the recommendation for a preferred route. Meetings and discussions have been held with the City staff during the process of the study to coordinate our efforts and to provide information as it became available.

The study was accomplished with personnel from Dames & Moore augmented by the professional services of the following four consultants. Geological data gathering was performed with the assistance of Logistics International Consultants and PSC Associates, Inc. P.B.Q.&D. Inc. prepared the cost and construction feasibility comparison of the alternative routes. Dr. Tor L. Brekke participated in reviewing the engineering geology and construction feasibility. The assistance of these four consultants are gratefully acknowledged.

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It has been a pleasure to work with the City's staff on this interesting and challenging project, and we look forward to assisting you during the subsequent design and construction stages.

Very truly yours,

DAMES & MOORE

Joseph J. Jeno
Partner

JJJ:WCW:jss
(10 copies submitted)

cc: City and County of San Francisco (10)
Attention: Mr. F. Moss

City and County of San Francisco (30)
Attention: Mr. D. Champeau

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Appendix C - Construction Feasibility, Preliminary Cost Estimates

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# EXECUTIVE SUMMARY

The purpose of this study was to investigate the subsurface geotechnical conditions across the Richmond District of San Francisco in order to recommend the most favorable alternative route for the proposed Transport Sewer. This report also provides the data and discussion of the geotechnical conditions which will be encountered during construction of the sewer.

The proposed Richmond Transport Sewer will upgrade the existing sewer system which has insufficient capacity to handle the wet-weather flow, resulting in untreated sewage overflowing directly into the ocean. The proposed sewer will be of sufficient capacity to transport the sewage to the treatment plant, reducing the number of overflows into the ocean and enabling the City to meet the guidelines for water quality which are presently being reviewed by regulatory boards.

The results of the geotechnical investigation and route selection study indicate that construction of the proposed Richmond Transport Sewer is feasible. In particular, the investigation and route selection studies show the Preferred Route through the Northern Corridor with the eastern terminus at the Lobos Creek area of the Presidio to be the most beneficial with respect to cost and construction feasibility, and to have the least potential construction impact on the neighborhood.

The seismic analyses indicate that in the event of strong earthquake shaking there is low to moderate risk of damage in certain localized areas along the alignment of the proposed sewer. No active faults have been identified in the project area, and distortion or rupture of the sewer by fault displacement is considered very remote. It is our opinion that any adverse effects can be mitigated by consideration during design.

An environmental impact study for the proposed sewer project may have an effect on the preferred alignment as developed during this geotechnical investigation.

On the basis of the geotechnical data obtained for this study three alternative route corridors were chosen and the comparative benefits of each

corridor were analyzed. The investigation and route selection study concluded that the Preferred Route through the northern portion of the Richmond District and through Lincoln Park to be the most beneficial with respect to cost, engineering, and construction feasibility. The studies presented in Appendix B, Route Selection by Computer Modeling (GIMS), and Appendix C, Construction Feasibility/Preliminary Cost Estimate, both concluded that the most suitable route for the tunnel should, where possible, be mined in rock rather than in soil, and should follow an alignment under undeveloped park land as opposed to residential areas.

The Preferred Route has a total alignment of about 11,100 feet and the principal engineering feature along the route is the construction of a 9,100 foot long tunnel, of which about 7,900 feet would be in rock and about 1,200 would be in soil. The sewer would pass under the Sutro Heights Park, Lincoln Park, and the Seacliff area as shown on Plate 1. In the Seacliff area, where the tunnel transitions from rock into soil, the Preferred Alignment runs beneath El Camino del Mar, with the eastern portal at the Lobos Creek area of the Presidio. The western tunnel portal would be located in the base of the bluffs at Sutro Heights Park. Along the Great Highway about 2,000 feet of cut-and-cover construction is required to complete the sewer between the Sutro Heights Park and the project limits at Fulton Street. Considering the possible corridors, it is our opinion the the Preferred Route has the least potential construction impact on private and public structures, and the residents and businesses of the Richmond District.

# FINAL REPORT
# GEOTECHNICAL INVESTIGATION
# ROUTE SELECTION STUDY
# RICHMOND TRANSPORT SEWER
# SAN FRANCISCO, CALIFORNIA

## 1.0 INTRODUCTION

### 1.1 General

This report presents the results of the Final Geotechnical Investigation (Phase III) for the proposed Richmond Transport Sewer. It incorporates the findings of both the Preliminary Areal Study (Phase I) dated May 20, 1978 and the Alternative Route Study (Phase II) dated October 17, 1978. The maps and subsurface sections presented in the two preliminary reports have been revised for the final report, and therefore, neither the Phase I nor Phase II reports are needed for an understanding of this report.

Attached to this report are four appendices. Appendix A presents a detailed description of each rock and soil type discussed in the text, together with a description of the field explorations and laboratory testing programs. The boring logs and test results are also presented in Appendix A. Appendix B is a route selection study conducted by computer modeling. Appendix C presents a discussion of construction feasibility of the alternative routes, and presents an estimate of the comparative construction costs. The seismic analyses as related to the design and construction of the sewer are presented in Appendix D.

The study area, which is shown on the Site Plan, Plate 1, covers the western portion of the Richmond District of San Francisco. All of the region from Golden Gate Park north to the Pacific Ocean and from 17th Avenue west to the Great Highway is included. Also included is all of Lincoln Park and Fort Miley, a portion of the Golden Gate National Recreation Area, (GGNRA) and a portion of the U.S. Army Presidio in the vicinity of Lobos Creek.

### 1.2 Purpose of the Investigation

The purpose of the investigation was to provide recommendations for the most favorable route for the Transport Sewer from the geotechnical standpoint and to provide geotechnical parameters for the design of the sewer. To this end, the three phases of the investigation were conducted as follows:

Phase I: To provide general areal information as to the subsurface soil and geologic conditions throughout the study area and identify favorable corridors for the sewer alignment;

Phase II: To provide additional studies as necessary to compare the various corridors and select a single "preferred" route;

Phase III: To perform additional final studies to provide specific information on subsurface soil and geologic conditions along the "preferred" route, with a discussion of the route selection process, construction conditions and suggested construction procedures for the various subsurface conditions found in the study area.

Also included in the Phase III report is a seismic study, which discusses the regional seismicity and seismic risk at the site, the site response to earthquake motion, the possibility of liquefaction occurring at the site, tunnel response and modes of damage which may occur, and general design measures to mitigate such damage.

Additional portions of the geotechnical investigation to be presented as future supplements to this report are:

1) Consultation during design of the sewer to provide specific geotechnical design parameters as the route, the method of construction and contracting, and final design configuration are finalized.

2) An engineer's cost estimate, to be made as the sewer design is completed.

## 1.3 Proposed Construction

The proposed Transport Sewer will collect the combined sewage and stormwater from the northeastern half of the study area and transport the flow to the southwest corner of the study area. As shown by the surface contours on the Site Plan, Plate 1, surface drainage is roughly divided across the study area by a northwest-southeast trending topographic ridgeline running through George Washington High School. The proposed Transport Sewer would carry nearly all of the stormwater runoff and sewage originating north and east of this divide, thereby replacing several existing outfalls in the Lobos Creek and Seacliff neighborhoods and a smaller diameter transport sewer tunnel constructed in 1938.

The western terminus of the Transport Sewer has been fixed by the City at the intersection of Fulton Street and the Great Highway, where it would join the Westside Transport Sewer at an invert elevation* of about zero. Location of the eastern terminus was not specified, however most of the large collector sewers with which the Transport Sewer must connect are located under Lake Street, north of Lobos Creek, and under the Seacliff neighborhood as shown on Figure 2 of Appendix C. The gradient of the proposed sewer was nominally set by the City at 0.002, however it is our understanding that there is some flexibility to this value. The elevation of the Transport Sewer must meet the constraints of a western terminus at Fulton Street and the Great Highway at Elevation zero, and a maximum starting elevation limited by the elevation of the existing collector sewers which would feed it. Depending upon the location of the eastern terminus, and the route chosen, the sewer could be from about 9,800 to 15,000 feet long.

Within these limits, most of the sewer profile will be located well below the ground surface and will therefore be a mined tunnel regardless of the route selected. Near the western end, and possibly the eastern end as well, depending upon the route chosen, the sewer will be at shallower depths making cut-and-cover construction practical.

At the present time the existing combined sewage is transported under the topographic ridgeline by the 6 foot horseshoe-shaped Richmond-Sunset Sewer Tunnel constructed in 1938 (Plate 2). This tunnel is of insufficient capacity to carry the combined flow during periods of heavy rainfall, whereupon overflow occurs, resulting in the discharge of raw sewage into the ocean through several existing outfalls.

The diameter of the proposed Transport Sewer is contingent upon the number of overflows which may be permitted each year. At the present time the question of how many overflows may occur is still under consideration by regulatory and review agencies; however, it is expected that possibly as many as eight overflows may be allowed each year. The original design assumption was based on one overflow and a sewer diameter of 15 feet. This may be

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*All elevations in this report are in feet and refer to the City and County of San Francisco datum, which is 8.616 feet above Mean Sea Level.

revised downward to a diameter of between about 9 and 13 feet depending on the number of overflows allowed.

An environmental impact study currently being prepared by others may have a potential effect on the alignment of the proposed sewer.

## 1.4 Methods of Investigation

### 1.4.1 General

Several different methods of investigation were utilized to obtain information about the subsurface conditions throughout the study area and to compare the various possible routes. Working closely together were the geotechnical disciplines of soil mechanics, earthquake engineering, and geology; working semi-independently were the disciplines of computer modeling and construction feasibility/cost estimating. Preliminary results were given to the City at several meetings held during the course of the study and in the Phase I and Phase II preliminary reports.

Dames and Moore was assisted in the soils and geological investigations by Logistics International Consultants of San Francisco and PSC Associates, Inc. of Mountain View. Engineering geologists from these firms worked with Dames and Moore in the geological mapping, logging of the test borings, laboratory testing, and in preparation of report plates.

### 1.4.2 Subsurface Soils Investigation

Information about the subsurface soils and ground water conditions was obtained by a literature search for existing soils data, and by a field investigation which consisted of drilling 33 small-diameter test borings at the locations shown on the Site Plan, Plate 1. The borings were advanced by conventional rotary-wash drilling methods using a biodegradable (Revert) drilling fluid. In all cases, except Borings 17, 32, and 33, the borings were drilled to a depth of approximately one tunnel diameter or more below the proposed tunnel invert level, and a standpipe piezometer was installed to permit long term measurement of the ground water level.

Disturbed and undisturbed soil samples recovered from the test borings were examined and classified visually, and selected samples were subjected to laboratory testing for classification, strength, permeability and swelling behavior. Much of the drilling was through rock strata and a significant footage of rock was cored using diamond-bit core barrels. A more detailed

description of the field explorations together with the Logs of Borings and laboratory test data are presented in Appendix A.

### 1.4.3 Geological Investigation

The geological investigation evaluated both the regional and the site geology. An extensive literature search was performed in which existing geological reports, as well as available accounts of the construction of several tunnels in San Francisco*, were studied.

A field study was carried out which consisted of reconnaissance mapping of all bedrock outcrops found within the study area and detailed mapping of exposures along the coastline from former Playland-At-The-Beach area to Bakers Beach. The field studies were supplemented by examination of available aerial photographs and logs of the rock core recovered from the test borings. To help infer the nature of the geologic structure between test borings, a limited magnetometer survey was performed in Lincoln Park. Geophysical surveys were not performed outside of the park because it was concluded that interference from traffic "noise", underground utilities, and pavement would preclude acquisition of reliable data for interpretation. Where appropriate, the regular Log of Boring in Appendix A is followed by a special Geologic Log which provides a detailed description of the rock types encountered and their structural properties.

### 1.4.4 Route Selection by Computer Modeling

Route selection by computer techniques was also employed as part of the investigation, using Dames & Moore's Geographic Information Management System (GIMS). The GIMS analysis was an office study conducted independently of the subsurface geotechnical study. The technique used is commonly called computerized overlay suitability mapping, and the basic steps are as follows:

1) Subdivide a base map of the subject area into a large number of small cells.

2) Identify the issues of concern for route selection. In this study the issues identified were: land use, cost of construction (soil or rock type to be excavated), and cover impact (depth and type of cover over the tunnel).

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*See end of text for References.

3) Compile all source data necessary for the study, such as ground surface elevation, distribution of soil types, and types of land use.
4) Assign the source data to each cell to produce source data maps. Combine various source maps or modify the data as needed to produce derived maps directly depicting each issue of concern.
5) Apply a weighting value to each data category based on the feasibility or desirability for tunnel construction, to produce issue maps.
6) By computer overlay methods, sum all of the issue maps, cell by cell, and compute the route having the lowest combined resistance.

A significant feature of the GIMS approach is that the relative values or weights assigned to the selection criteria and to the issue maps may be easily adjusted to check the sensitivity of the computed optimum route to the input data. Thus, for example, the relative desirability of locating the tunnel beneath a street versus locating the tunnel beneath private property could be adjusted on a scale of 0 to 9. In a like manner the relative weights of say, the land-use issue map versus the cost-of-construction issue map could be adjusted. A detailed description and the results of the GIMS analysis is included as Appendix B to this report. The results of the study are presented on Plates B-1 through B-3.

### 1.4.5 Investigation of the Comparative Costs and Construction Feasibility

Comparison of alternative routes was also made by evaluating construction feasibility and estimating comparative construction costs. Using information obtained during the subsurface explorations, our consultants, PBQ&D Inc., performed this study independently. The results are presented in their report, Construction Feasibility and Comparative Cost Estimates, attached as Appendix C to this report.

### 1.4.6 Seismic Investigation

The seismic analysis was undertaken to evaluate a) the magnitude and probability of strong ground shaking which might occur as a result of a nearby earthquake during the life of the structure, and b) the ground and tunnel response which would be expected from such ground shaking.

The regional seismicity and seismic risk at the site were evaluted by first preparing maps of all major active faults and epicentral locations of recorded earthquakes near the study area, based upon published literature. Secondly, a computerized statistical analysis was used to evaluate the probability that specific levels of shaking would occur within two selected time periods.

The analysis of site response to ground shaking was based upon a literature search to review how other sites with similar soil conditions had behaved during past earthquakes, and upon a method of wave propagation analysis developed at the University of California at Berkeley. Four different subsurface profiles were used to model the range of typical site conditions. Appropriate soil, rock and ground water parameters for the wave propagation analysis were selected from data obtained during the geotechnical investigations and supplemented by data from subsurface investigations performed by others.

As part of the site response studies, an analysis was made of the potential for soil liquefaction during ground shaking. This analysis was based upon the results of dynamic triaxial tests of sand samples obtained during the subsurface soils investigation and also upon a method of liquefaction analysis developed at the University of California at Berkeley which uses the penetration resistance (blow count) of the soils recorded during the test boring program. This analysis was supplemented by a literature review, including observations of the study area made during and just after the 1906 earthquake.

The final portion of the seismic study is concerned with structure response to ground shaking. As there are few analytical methods available to theoretically evaluate the response of buried structures to earthquakes, particularly in rock, this section is based primarily on published accounts of the performance of other tunnels during past earthquakes.

The results of the seismic study are summarized in Section 3.0. Details of the analyses, the methods and assumptions used, and the test results are presented as Appendix D to this report.

### 1.4.7 Consultation

Consultation regarding construction feasibility and engineering geology has been provided by Dr. Tor L. Brekke of Berkeley, California, a noted expert on tunnel design and construction. Dr. Brekke reviewed the progress of the geological reconnaissance at several stages and made recommendations for areas of further studies and methods of data presentation. He has also offered valuable insight on construction methods and feasibility, particularly stressing the importance of implementing suitable contract procedures which will best serve both the City and the Contractor.

## 2.0 SITE CONDITIONS

### 2.1 Surface Conditions

The major portion of the study area in the Richmond District is fully developed for residential use, with some light commercial businesses such as retail stores and service stations. Locations of six public schools and one private school are shown on the Site Plan, Plate 1. Virtually no undeveloped private land exists, except along the Great Highway north of Fulton Street which is the former site of Playland-At-The-Beach.

As shown on the Site Plan, portions of the study area are park or military lands. These areas have several significant structures, notably the Palace of the Legion of Honor in Lincoln Park and the Veteran's Administration Hospital complex in Fort Miley. The only significant structures in the portion of Golden Gate Park within the study area are a police station at 37th Avenue and a sewage pump station at 48th Avenue.

The surface elevations throughout the study area are indicated by the contours on Plate 1, which show the maximum elevation of about +370 feet in Lincoln Park, and the topographic ridgeline trending northwest-southeast through the campus of George Washington High School and across Lincoln Park. At Fulton Street and the Great Highway, the elevation is about +12 feet.

There are no existing surface streams or lakes in the study area except Lobos Creek in the Presidio. All storm runoff is handled by surface infiltration and the combined sewer system, except along the northern bluffs which drain directly into the Pacific Ocean.

### 2.2 Subsurface Soil Conditions

With minor exceptions, the subsurface soils overlying bedrock can be classified into two main types, dune sand and Colma Formation sand. These soil types cover virtually the entire study area. Other soil types, occurring sporadically or in localized areas include beach sand, clayey marsh or lagoon deposits, colluvium or slope wash, manmade fill, and mixed streambed deposits. A detailed description of each of the soil types is given in Appendix A. Grain-size distribution, permeability, strength, and classification test results on dune and Colma sands are presented in Appendix A together with the Log of Borings.

The overall depth of soil may be estimated from Plate 2 which shows the ground surface elevation and contours of the estimated elevation of the bedrock surface. Plate 3 shows the contours of the estimated elevation of the bottom of the dune sand. Plate 3 may also be taken to approximate the upper surface of the Colma Formation, since in general the dune sand directly overlies the Colma sand except where the Colma sand is not present; in this case the dune sand directly overlies bedrock or colluvium-covered bedrock.

Dune sand is a uniform, fine-grained clean sand, deposited by wind. Except for a few isolated outcrops of Colma sand and bedrock, dune sand constitutes the surficial soils over the entire site and ranges from a few feet to over one hundred feet in thickness. As encountered in the borings the dune sand is generally medium dense to dense.

The Colma sand underlies the dune sand. Occasionally, thin clayey marsh deposits are interposed between the dune and Colma sands. Colma sand is fine-grained, but unlike the dune sand, generally has a silt binder which imparts some cohesion. Colma sand is generally dense to very dense and weak cementation by iron oxide occurs locally. The contact between the Colma sand and underlying bedrock is commonly marked by clay-rich colluvial deposits.

The occurrence of dune and Colma sands and colluvium is generalized on the Subsurface Sections, Plates 5B through 5G, all of which have an exaggerated vertical scale. The locations of the sections are shown on Plate 5A.

### 2.3 Ground Water

Plate 4 shows the estimated elevation contours of the ground water surface. In preparation of the map, the water level readings taken from the test borings were supplemented by historical data contained in a 1913 report by the City of old water wells drilled in the study area (O'Shaughnessy, 1913). This report is a comprehensive collection of data from all wells that existed in the City and County of San Francisco in 1913. In addition, a limited amount of ground water data was obtained from records of borings by others, and accounts of the construction of the Mile Rock Sewer Tunnel and

the Richmond-Sunset Sewer Tunnel (Taylor, 1916; Rothschild, 1938). The locations of these tunnels are shown on Plate 2.

The water level measured in most of the test borings has varied from a few inches to a few feet since installation, and where appropriate, more than one level is shown on the Log of Boring to indicate the range of variation. Along the Great Highway it is possible that the ground water level will exhibit a small daily fluctuation due to tidal influence.

On the basis of the water level readings and available literature, it appears that the water table throughout the study area is relatively stable. About two-thirds of the developed area is paved or covered by structures and thus unavailable for rain water infiltration. There are relatively few wells in the study area and these are located in the Presidio near Lobos Creek (domestic water supply), and in Golden Gate Park near the north windmill (for irrigation). No private wells are currently known to be operating in the study area.

An anomaly has been recorded in Boring 13 at the Palace of the Legion of Honor. At this location, a perched water table in the soils over bedrock was measured at elevation +333 feet, and a lower water table deep in the bedrock was measured at elevation +93 feet. None of the other test borings have recorded water levels corresponding to the lower water level in Boring 13, thus the extent of this perched condition is not known. If an extensive area is involved, the lower water table would be beneficial for tunnel construction. However, because of the highly jointed nature of most of the bedrock encountered, it is our recommendation that the presence of a lower water table, hydraulically isolated from the surface, should not be relied upon beyond the immediate vicinity of Boring 13.

On the basis of the rock core recovered for this investigation, it is our opinion that the bedrock contains relatively little water as compared to the soil above it. This conclusion is supported by O'Shaughnessy's 1913 report where it was recorded that many attempts to drill water wells in the bedrock have been made in San Francisco, but rarely have worthwhile quantities of water been obtained. None of the rocks of the Great Valley Sequence or Franciscan Assemblage are very porous. The great number of

sheared and fractured zones which have been encountered probably contain most of the water to be found in the bedrock. Other tunnels constructed in San Francisco have experienced localized substantial inflows of water when such zones were encountered.

## 2.4 Regional Geology

The study area lies in the Coast Ranges Geologic Province of California. Two main bedrock units have been distinguished in this zone: the Franciscan Assemblage and the Great Valley Sequence. Both units are Jurassic to Cretaceous in age (about 90 to 180 million years old).

The Franciscan Assemblage in most localities is composed of north to west-northwest trending lithologic belts. These belts are generally characterized by the following rock assemblages (detailed descriptions of each rock type are presented in Appendix A):

1) moderately well-bedded graywacke (a type of sandstone) and shale with minor interbedded chert and volcanic rock;
2) metamorphosed graywacke, chert and greenstone with associated faint to strong development of a metamorphic fabric;
3) massive arkosic (feldspar-rich) sandstone and shale; and
4) melanges composed of a mixture of graywacke, greenstone, chert, serpentine and metamorphic inclusions in a matrix of sheared shale (Bailey and others, 1964; Berkland and others, 1972; Blake and Jones, 1974).

These lithologic belts are commonly fault bounded and exhibit substantial lateral variation in lithology, mineralogy and structure. For these reasons strict correlation among exposures of the Franciscan is generally not possible. Many authors, however, have divided the Franciscan into major geographic belts based on similarities in lithology or structure, or both (Bailey and Irwin, 1959; Berkland and others, 1972). On this basis, geographically, the study area lies in the Coastal Belt which is characterized by massive graywacke with minor shale and very rare greenstone and chert; lithologically however, the rocks of the study area more closely resemble those of the Central Belt in that shale matrix melange, greenstone and thrust sheets occur commonly.

Rocks of the Franciscan Assemblage were deposited in a marine environment along the western portion of the North American Plate. The graywacke and interbedded siltstone and shale represent deposition by turbidity currents on the continental slope and rise. Regions where graywackes predominate probably represent inner (proximal) fan and channel deposits. Interbedded siltstone and shale deposits probably represent outer (distal) fan deposits. Alternating sequences of massive graywacke and interbedded graywacke, shale and siltstone represent the migration of the channel across the fan. Chert is generally deposited in quiet, deep ocean basins, somewhat isolated from the influx of continent derived debris. In the Franciscan, however, chert was often deposited in association with the eruption and intrusion of lavas and sills which were subsequently altered to greenstone.

Three features of the Franciscan Assemblage suggest that deposition of these rocks was intimately associated with tectonic activity: 1) the lack of coherent stratigraphy; 2) the presence of extensive shear zones; and 3) the occurrence of blueschist grade metamorphism. The exact nature of this tectonic activity is not certain. Possibilities are: 1) subduction (the underthrusting of one crustal plate beneath another, resulting in increased temperature and pressures), suggested by the occurrence of blueschist facies metamorphism; 2) strike-slip faulting, suggested by current plate motions; and 3) oblique subduction, which combines elements of the first two possibilities.

The Great Valley Sequence is composed of interbedded shale, siltstone, sandstone, and conglomerate. These rocks are well bedded and, on a regional scale, shale is more prevalent than sandstone. Sedimentary structures such as graded bedding, sole markings and flute casts suggest that these rocks were deposited by turbidity currents on a continental slope (Blake and Jones, 1974). The main features of the rocks of the Great Valley Sequence which can be used to distinguish them from the rocks of the Franciscan Assemblage are: 1) the greater continuity of beds; 2) the relative lack of deformation and metamorphism; 3) the lower sandstone to shale ratio; and 4) the relative enrichment in potassium feldspar (Bailey and others, 1964; Blake and Jones, 1974).

The Great Valley Sequence was deposited in a tectonically quieter environment than the Franciscan, which resulted in its greater continuity of bedding and its relative lack of deformation.

During the interval between Cretaceous and Quaternary time the Great Valley Sequence is generally interpreted to have been emplaced over the Franciscan Assemblage along a low angle, east dipping thrust fault (Bailey and others, 1964; Ernst, 1970; Hsu, 1971; Berkland and others, 1972; Suppe, 1973; Blake and Jones, 1974), known as the Coast Ranges Thrust. Also during this period the tectonic and depositional regime which produced the Franciscan Assemblage evolved to the present day San Andreas Rift Zone system. The present system involves the Pacific Plate moving to the northwest relative to the North American Plate along several northwest trending, right lateral faults as shown on Plate 8. The dominant fault of the system is the San Andreas Fault which lies approximately 3 miles west of the study area. Another major fault of this system, the Hayward Fault, lies about 15 miles east of the study area. Risks associated with activity on these faults are discussed in Section 3.0, the seismic study, and in Appendix D.

Deposition from the Pleistocene (1.85 million years ago) to the present was closely related to global fluctuations in sea level primarily related to glaciations, but also influenced by local tectonic movements. The Colma Formation was deposited in the study area during the Pleistocene. At lower elevations the character of this formation is suggestive of deposition in an estuarine environment (Schlocker, 1974). At higher elevations the Colma Formation appears to consist of alluvial (stream), colluvial (slope wash) and aeolian (wind) deposits (Schlocker, 1974). Deposition of the Colma over the study area probably occurred in an extensive complex of bays, shallow inlets and channels similar to the present Drakes Bay and Drakes Estero on the Point Reyes Peninsula.

During the latest interglacial period, erosion and weathering of the Colma Formation occurred. Since this time, wind transported dune sands picked up from the ocean beaches have been deposited over the weathered Colma surface.

## 2.5 Site Geology

### 2.5.1 General

The bedrock geology of the Richmond District has a complex stratigraphy and structure. Outcrops occur primarily along the coast and in Lincoln Park. The bedrock of the rest of the district is covered by soil deposits or has been obscured by urban development. Previous geologic mapping in the area was reported by Schlocker, Bonilla and Radbruch (1958), Bonilla (1965,1971), Blake and others (1974), and Schlocker (1974). Two bedrock units and eight bedrock types have been distinguished in the Richmond District. The two bedrock units are the Great Valley Sequence in the west and the Franciscan Assemblage in the east, which are separated by a wide shear zone (the City College Fault Zone). The eight rock types are: 1) graywacke; 2) sandstone; 3) melange; 4) greenstone; 5) interbedded siltstone and shale; 6) serpentine; 7) chert; and 8) limestone.

Geologic maps at ground surface and at tunnel invert level are presented on Plates 6A and 6B. An interpretive cross section of the bedrock geology along the preferred tunnel route (described in Section 4.4.3) is presented on Plate 6C. Detailed descriptions of each rock type, the Logs of Borings and Geologic Logs are provided in Appendix A. In the following discussion the description of the units and rock types will proceed from west to east.

### 2.5.2 Great Valley Sequence

Rocks which have been identified as part of the Great Valley Sequence underlie the western portion of the study area. Excellent exposures of these rocks occur in the Sutro Baths and Cliff House area. The Great Valley Sequence in the Richmond District can be divided into two units: 1) a sandstone unit; and 2) a sheared, interbedded siltstone and shale unit.

Exposures along the coast indicate that the sandstone unit is dominated by massive, very hard arkosic sandstone, with relatively few siltstone and shale lenses. The description of the construction of the Mile Rock Tunnel (under 48th Avenue) by C.M. Taylor (1916), however, suggests that there may be moderately extensive lenses of interbedded siltstone and shale underlying the eastern portion of Sutro Heights Park. Boring 15, near the southeastern

corner of Sutro Heights Park, encountered significant siltstone and shale lenses, corroborating this interpretation. There may, therefore, be more lenses of siltstone and shale in the sandstone unit than is apparent from exposures along the coast.

The interbedded siltstone and shale unit which lies immediately adjacent to the City College Fault Zone, is approximately 500 feet wide, with beds generally 1 to 6 inches thick. Bedding is highly contorted and the unit exhibits substantial shearing. Tectonic inclusions of massive arkosic sandstone up to 50 feet in size have been observed. The percentage of swelling clay in the sheared shale matrix appears to increase near the City College Fault Zone. The shearing and tectonic inclusions are probably related to past activity on the City College Fault. The attitude of the unit appears to be subparallel to that of the City College Fault Zone, i.e., northwest trending and nearly vertical.

Representative examples of the massive arkosic sandstone were obtained from Boring 29 and representative examples of the interbedded siltstone and shale were obtained from the upper portion of Boring 29 and from Borings 15 and 33.

### 2.5.3 City College Fault Zone

A wide melange zone separates rocks of the Great Valley Sequence on the west from the Franciscan Assemblage rocks on the east. The zone may simply be an isolated unit of melange, as occasionally found elsewhere in the Franciscan Assemblage; however, it is generally interpreted to be the northwestern continuation of the City College Fault Zone (Bonilla, 1961; Blake and others, 1974; Schlocker, 1974). This melange zone is approximately 1000 feet wide, and characterized by a sheared shale matrix with up to 40 percent tectonic inclusions. These inclusions are commonly cobble to boulder size but may exceed 200 feet across. Based on exposures along the coast about 20 percent of this melange zone was observed to have inclusions which exceeded 10 feet in size.

Representative exposures of this zone occur along the coast. North of the Veterans Hospital complex the sheared shale matrix is rich in montmorillonitic clays and there has been extensive landsliding.

The fault zone appears to be a northwest striking, nearly vertical feature within the study area. The direction of displacement on the City College Fault is not certain. The northwest trend of this fault, its vertical dip, and the fact that it juxtaposes rocks of the Great Valley Sequence on the west against Franciscan rocks on the east suggest that this fault may be an ancestor of the present day San Andreas Rift Zone, which is a right-lateral, strike-slip fault system.

The maximum age for the City College Fault is upper Cretaceous because the rocks in the melange zone are Jurassic to Cretaceous rocks of the Franciscan Assemblage and the Great Valley Sequence. No evidence of faulting has been observed in the overlying Colma or dune sand deposits which are Pleistocene and younger in age; however it is not certain that the evidence of displacement would be preserved in such materials (Bonilla, 1961). Activity on the fault occurred after upper Cretaceous time and is most likely to have occurred during the Tertiary period. Because no evidence has been found of displacement of Pleistocene or younger strata, this fault has been classified as inactive by Jennings et al. (1975) (see Plate 8). No evidence of movement along this fault zone was observed during or after the 1906 earthquake.

### 2.5.4 Franciscan Assemblage

The Franciscan Assemblage underlies the study area east of the City College Fault Zone. The Franciscan here is characterized by sections of jointed rock masses separated by shear zones or faults. The jointed rock masses are commonly composed of thick bedded graywacke with minor siltstone and shale, and more rarely chert. Shear zones and faults are generally marked by melange zones and serpentine lenses. As exposed along the coast and observed in the borings, the Franciscan in this locality can be divided into four units. From west to east these units comprise a thrust sheet-melange complex, a bedded graywacke unit, a melange zone, and another bedded graywacke unit. The relative location of these four units has been postulated as shown on Plate 6C.

The thrust sheet-melange complex is characterized by large jointed to brecciated (crushed), tectonic slabs separated by relatively narrow shear

zones marked by serpentine. This complex is exposed along the coast from 1000 feet east of Land's End to just west of Land's End. At least three thrust faults were identified in the field by curvilinear strings of serpentine outcrops. To a limited extent these thrust sheets were mapped through Lincoln Park on the basis of the results of a magnetometer survey. The thrust faults appear to strike approximately N45-60°W and to dip gently, 10-35°, to the southwest. Borings 13, 20, 23, 28 and 30 exhibit numerous shear zones; it is therefore considered likely that there are other thrust faults in addition to the three identified along the coast, and that there exists a complex series of southwest dipping thrust sheets.

This zone can be considered a melange composed for the most part of coherent jointed or brecciated inclusions with a lesser proportion of sheared shale matrix. The tectonic slabs are primarily composed of greenstone and graywacke, and the shear zones consist primarily of serpentine and sheared shale. It is very difficult to estimate the percentage of tectonic inclusions versus the percentage of sheared shale matrix. Based on field mapping and the boring logs we anticipate that at least 60% of this zone will be composed of tectonic inclusions and that this value could be as high as 75-80%. As much as 80% of these inclusions may be composed of highly fractured greenstone.

East of the thrust sheet-melange complex and west of Phelan Beach is a unit of jointed, bedded graywacke with minor interbedded siltstone and shale. This unit forms steep cliffs along the coast with coves and caves formed along the weaker shear zones and interbedded siltstone and shale zones. Representative samples of this unit were obtained from Boring 21. These beds generally strike north-south and dip moderately to the east (Plate 7A). The fractures and shear zones in this unit strike predominantly north-northwest and north-northeast and dip steeply (Plate 7B). A chert/sheared shale zone within this western graywacke unit was observed in exposures along the coast and is noted on Plate 6B. The zone contains highly fractured chert, graywacke and sheared shale, similar to other melange zones, and may be as much as 200 feet wide. Since the zone was not encountered in the borings, and landslides have obscured its contact relations, the orientation

of this zone is uncertain. It may be a part of the Phelan Beach melange zone.

The next unit eastward in the Franciscan is a probable melange zone extending south from Phelan Beach. Three features of the area suggest that it is a melange zone:

1) the presence of blocks of limestone, chert and serpentine on the beach: rock types which are not found in adjacent exposures and, in the case of the limestone, have not been observed elsewhere in the study area;

2) the change in character and orientation of the graywacke units on the east side of the beach as compared to the west side; and

3) the extensive landsliding in the area above the beach.

The exact attitude of the shear zone is not known but an eastward dip is suggested by two features:

1) the contact relations between bedrock exposures and landslide and colluvial material on either side of the beach; and

2) the presence of a shale breccia unit in the upper part of Boring 27 which has been tentatively correlated with the shear zone at Phelan Beach.

Based on limited exposures and Boring 27 we estimate that this melange zone is about 500 feet wide. We anticipate that this melange zone will be dominated by sheared shale matrix, similar to the melange of the City College Fault Zone.

The easternmost unit, which extends from Phelan Beach to Baker's Beach, is characterized by massive graywacke with very minor siltstone and shale. In a few localities bedding was observed and has a strike of N60°W, dipping to the south (Plate 7C). This bedding orientation is distinctly different from that present in the graywacke unit west of Phelan Beach (Plate 7A). However, the rose diagram of the fracture and shear zone orientations (Plate 7D) shows predominant north-northwest orientations very similar to that found in the western graywacke unit (Plate 7B). The graywacke of the eastern unit is generally more massive and contains fewer shale and siltstone interbeds than the graywacke of the western unit. Representative samples of this unit were obtained from Borings 2, 6, 26, and 31.

## 3.0 SEISMIC CONSIDERATIONS

### 3.1 General

This section summarizes the results of our seismic studies that were conducted to evaluate:

1) the regional seismicity and the associated seismic risk at the site for the purposes of estimating the levels of ground motions that could occur within the study area during a major earthquake;

2) the seismic response of typical soil and rock profiles to the levels of earthquake shaking identified under item 1), and to estimate the resulting potential for soil liquefaction and slope instability;

3) the dynamic interaction between the sewer and the surrounding soil or rock, and to identify those portions of the alignment which may be subjected to critical loads or deflections.

On the basis of these studies, some portions of the sewer alignment which require special design considerations have been identified. Appendix D presents a more detailed explanation of the techniques used to develop the design input parameters, as well as a description of the analyses, and a discussion of the three items listed above.

### 3.2 Seismicity and Seismic Risk Evaluation

The major active faults in the San Francisco Bay Region are associated with the San Andreas system which includes the San Andreas Fault, the Healdsburg Fault, the Hayward Fault, the Calaveras Fault, the Sargent Fault and the San Gregorio Fault. These faults are oriented in a general northwesterly direction and have relatively well-defined locations, as shown on Plate 8. The site is located about three miles northeast of the San Andreas Fault and about 15 miles southwest of the Hayward Fault. While seismic activity on any of the faults could produce strong shaking at the site, the nearby San Andreas Fault is considered to represent the greatest potential hazard.

Since 1808, more than 1,500 earthquakes have been reported within 100 kilometers of the study area. Most of these were relatively recent

instrumental recordings of events that were too small to be felt. Only 303 of the recorded events had epicentral intensities greater than Modified Mercalli V, or Richter magnitudes equal to, or greater than 4.0.

The first seismological instruments in Northern California were placed on Mount Hamilton in 1887 and recorded the 1906 San Francisco earthquake. However, it was not until the early 1930's that a sufficient number of instruments had been installed to locate the epicenters of all Bay Area earthquakes greater than magnitude 4. Before that time, investigators located epicenters in population centers such as San Jose or San Francisco, where the motions were felt, even though the true centers of energy release were probably located somewhere else. A map of reported epicentral locations is presented on Plate 9.

The seismic risk at the site was evaluated by summing the assessed risk contributions from the individual faults surrounding the site. The study was carried out using a statistical method developed by Dr. Neville Donovan of Dames & Moore. The methodology of the risk analysis is described in Appendix D.

Expected peak surface accelerations at the site were calculated using two attenuation* relationships; one was developed utilizing earthquake data recorded on exposed bedrock or very stiff soil sites, and the other was developed from earthquake records at firm soil sites. Both cases were considered since the project site conditions vary from exposed bedrock to deep soil.

The computed seismic risk is expressed in terms of the probability that a given level of ground surface acceleration will be exceeded during the design life of the structure. The results are presented on Plates 10A (Soil Equation) and 10B (Rock Equation), for two assumed design lives of the sewer, i.e. 50 and 100 years.

The results of this study indicate a high probability that the site will experience moderate to strong ground shaking during the economic life of the structure.

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*Attenuation is defined as the reduction in the intensity of ground motion with distance from the zone of energy release.

As discussed in the geology sections of this report, no active faults have been identified in the project area. The City College Fault zone has been classified as inactive (Jennings, 1975). It is our opinion that distortion or rupture of the proposed sewer during its design life as a result of displacement of a fault within the project area is remote.

## 3.3 Seismic Response of Soil and Rock

The seismic response of the soil and rock at the site during a major earthquake was investigated in four stages: 1) an evaluation of soil and rock properties, water levels, and the blow count values as shown on the boring logs, 2) an evaluation of static and dynamic laboratory test results on representative soil samples, 3) performing a one-dimensional wave propagation analysis, using three different soil profiles to model the range of subsurface conditions at the site, and 4) a review of existing literature on seismic site response for conditions applicable to the present study.

### 3.3.1 Soil Response

The seismic response of the various soil profiles was evaluted by one-dimensional wave-propagation analyses, using 200-foot, 150-foot and 50-foot soil depths to model the range of site conditions. One-dimensional soil response analyses provide a good estimate of horizontal soil response to seismic shear waves and a reasonable estimate for a soil profile with a sloping rock boundary.

For the soil response analysis, the two design seismic motions selected were the S80°E component of the Golden Gate Park record of the 1957 San Francisco earthquake (maximum acceleration 0.13g) and this excitation multiplied by a factor of three (0.39g). The accelerogram was recorded on a rock outcrop and represents bedrock response to activity on a nearby section of the San Andreas Fault. An acceleration level of 0.39g corresponds to an event with a 13 percent probability of being exceeded within a 100 year design life, as shown on Plate 10B. On this basis, we believe that the record as modified is appropriate for the present analysis.

The two accelerograms were input as the bedrock surface motion to each of the three representative soil profiles and the soil response was computed using the one dimensional wave propagation analysis developed at the University of California, Berkeley (Schnabel et al., 1972).

The results of the soil response analyses are presented on Plate 11, which shows the peak accelerations and strain levels computed at the ground surface and at depths of 20 and 100 feet.

The soil response analyses indicate that peak accelerations will be greatest at the ground surface, significantly lower at shallow depths on the order of 20 feet, but then increase again with depth. The computed peak strain, however, was lowest at the ground surface and greatest at shallow depths.

### 3.3.2 Rock Response

The accelerations shown on Plate 10B have been computed from an attenuation equation based on accelerograms recorded on exposed bedrock surfaces. Plate 10B therefore represents the expected seismic response of the bedrock surface throughout the study area. It is generally accepted that peak accelerations and displacements in a rock mass decrease slightly with depth. The seismic response of the rock mass at some depth below the bedrock surface has been conservatively assumed to be the same as that occurring at the bedrock surface.

### 3.3.3 Soil/Rock Transition Response

Evaluation of case histories (Lawson, 1908; Seed, et al., 1972) and theoretical studies by others (Dezfulian and Seed, 1970) have shown that an amplification of motion occurs between a steeply emerging rock slope surface and the adjacent shallow soil. This general trend is shown on Plate 11, where the computed ground accelerations are greatest for shallow soil conditions and decrease for deepening soil conditions. However, the one-dimensional soil response analysis assumes a horizontal bedrock surface at each soil profile. Using the three soil profiles to simulate an emerging rock slope surface is a simplifying approximation.

Steeper rock slopes create greater disparity of wave amplitude and phase at the interface between the two materials. The magnitude of the response difference is generally greatest near the ground surface, and decreases with depth. However, the out-of-phase motion could cause high accelerations at the soil-rock interface. Body and surface wave displacements in the soil are likely to be higher than displacements in the adjacent

rock. Peak accelerations in the soil near the rock slope as estimated by a one-dimensional soil response analysis are generally slightly higher than those obtained from more sophisticated methods. The effects of an emerging rock slope on seismic response is discussed in greater detail in Appendix D.

## 3.4 Slope Stability During Earthquake Shaking

It is our opinion that soil and rock slope instability at the site during a major earthquake would not endanger the sewer except as discussed in the next section. It is possible that shallow sloughing may occur in the project area during strong shaking but deeper failures penetrating to the level of the sewer tunnel are unlikely. The only slopes of any significance which might affect the sewer at shallow depths are at the Sutro Heights bluffs and at Lobos Creek. In both cases it is considered unlikely that seismically induced slides could penetrate to the sewer level unless liquefaction occured in the soils at the base of the slopes. This condition is discussed in the following section.

## 3.5 Liquefaction Potential

The liquefaction potential in the sands above and around the sewer was considered by two methods: laboratory testing, and interpretation and evaluation of field blow count values. Both methods gave approximately comparable results. However, the analysis based on sampler blow count data had a broader data base and is therefore considered to be the more reliable indicator of liquefaction potential. Three different areas of potential liquefaction were considered, namely the Great Highway area, the north side of Golden Gate Park along Fulton Street, and the Lobos Creek area. The results of the analyses for the first two of these areas are presented on Plates 12A and 12B which compares the computed minimum penetration resistance required to resist soil liquefaction with the field blow count values.

The liquefaction analyses indicate that extensive liquefaction during strong shaking is unlikely to occur in the two areas considered. However, the variation of blow count data obtained from the borings suggests that during strong shaking liquefaction may occur in localized zones or pockets of looser soil. Evidence of liquefaction (sand boils, cracking, lateral spreading) was reported to have occurred 200 feet from the beach just south of Golden Gate

Park during the 1906 earthquake (Lawson, 1908). This occurrence may have been in loose fill created when the dunes in the area were leveled for development. No other instances of liquefaction in the Great Highway area during the 1906 earthquake were reported by Lawson. It is our opinion that these areas of liquefaction would probably be of minor extent and would not represent a serious risk to the sewer.

Adequate boring data to perform a liquefaction analysis was not available for the Lobos Creek area. It is our opinion, however, that the alluvium at the bottom of Lobos Creek could liquefy during a major earthquake. Many San Francisco area streambeds were reported to have liquefied during the 1906 earthquake (Lawson, 1908).

Liquefaction of the streambed deposits at Lobos Creek would represent a relatively small area of instability with respect to the tunnel structure. It is our opinion that the tunnel could be designed to safely span the creekbed in the event of liquefaction. If the tunnel is placed within the fill embankment for Lincoln Boulevard, the weight of the embankment on the streambed soils will decrease the probability of liquefaction. Liquefaction in the streambed near the base of the embankment slopes could result in some slumping of the Lincoln Boulevard embankment. If such slumping penetrated to the tunnel level, the sewer could be damaged unless special measures were incorporated in the design.

### 3.6 Seismically Induced Settlement

Seismically induced settlement of sand deposits occur as a result of volumetric strains generated during shaking. We have reviewed available data from case histories and experimental work (Seed and Silver, 1972; Pyke et al., 1974) and have concluded that seismically induced settlement should not be a serious problem.

The greatest settlement can be expected where the sand deposits are deepest, which is on the order of 200 to 250 feet in the study area. For these conditions, and assuming about half dune and half Colma sand, we estimate that seismically induced surface settlement would not be more than a few tenths of a foot. Settlement at some depth below the surface would be correspondingly less. On this basis it is our opinion that more sophisticated analyses are not warranted.

## 3.7 Dynamic Interaction Between the Sewer and the Surrounding Soil and Rock

For structures above ground the maximum dynamic loads and deflections are primarily determined by the inertial response of the structure to base motion. In contrast, inertia loads generally do not control the seismic response of a tunnel within the ground mass. The tunnel follows the ground motions since its mass and stiffness are much less than the combined mass and stiffness of the surrounding soil or rock. The tunnel cannot vibrate freely, and therefore cannot amplify the ground motions at its own natural frequency. The maximum tunnel loads and deflections will be determined not by ground accelerations, but by the relative ground displacements. Axial loads and axial strains usually control tunnel design, while bending and shear loads are less critical.

Tunnels have historically behaved satisfactorily as compared to surface structures during earthquake shaking. Earthquake-induced damage to tunnels in intact massive rock is usually very slight, even during major earthquakes (Dowding, 1978). Critical areas requiring extra strength and ductility in the tunnel liner are identified below:

1) Abrupt transition zones from rock to soil, particularly at shallow depths.

2) Abrupt transition zones from hard soil to soft soil, such as leaving natural soil under El Camino del Mar and entering the manmade fill of the Lincoln Boulevard embankment over Lobos Creek.

3) Abrupt transition zones from shallow soil to deep soil deposits.

4) Areas of potential soil liquefaction during strong ground shaking, such as at Lobos Creek.

5) Abrupt changes in structure section geometry, junction structures, and sharp bends in the tunnel alignment.

In conclusion, it is our opinion that the risk of earthquake induced damage to the sewer is slight to moderate, provided special attention is paid to the critical areas mentioned above. Comparison of alternative routes with regard to seismic risk does not indicate that any particular route would be significantly better or worse than the others.

## 4.0 DISCUSSION AND RECOMMENDATIONS

### 4.1 Route Selection Criteria for Tunnel

In determination of the preferred route for the sewer alignment three basic route selection criteria were used in this study:

1. The sewer must be located so that gradient, alignment, and terminus meet the hydraulic requirements necessary to satisfy the intended purpose of the transport sewer.
2. The sewer construction must be economical as compared to construction on alternative routes.
3. The sewer construction must be within acceptable limits with regard to the risk of distress or damage to private and public structures.

Other criteria, such as disturbance or nuisance to businesses or private citizens during construction, and effects of construction on native flora or fauna, were identified but consideration of their effect on alternative routes was beyond the scope of this study.

The first criterion, that of compliance with hydraulic requirements, essentially restricts the tunnel alignment only at the two ends of the sewer. The location of the western end of the sewer is precisely dictated by hydraulic requirements to connect with the proposed sewer along the Great Highway, and the eastern end must fall within a relatively small geographical area in order to connect with the existing sewer system under and north of Lake Street.

The second criterion is concerned with risk to private and public property caused by the construction and operation of the sewer, including risk to the tunneling contractor. This report deals principally with risk as related to undesirable ground movement: loss of ground, squeezing, flowing or raveling ground, or subsidence of the ground surface. Some of these problems of ground movement are caused by, or accompanied by, ground water flow into the tunnel. Fortunately, a route chosen for economic reasons because it offers the best tunneling conditions will probably compare favorably with other routes in terms of risk, as the two criteria are generally compatible. In evaluating alternative routes, the criterion of acceptable risk, as

regards the consequences of surface subsidence, was assumed to vary across the study area depending upon the nature of surface usage.

The third basic criterion, economy, is primarily dependent upon selection of a route offering the best subsurface conditions for tunneling, and making the route as short as possible. Listed in order of importance, the best ground conditions for tunneling would minimize ground water problems, excavation problems, and ground stability problems (Schmidt, 1974). Other cost factors, such as the obtainment of easements to private property, are beyond the scope of this study, but are probably small as compared to the effects of ground conditions and tunnel length.

## 4.2 Excavation Characteristics of Soil

### 4.2.1 Dune Sand

Because of the uniformity of dune sand, the excavation characteristics in this soil can be predicted with reasonable confidence. It is unlikely that naturally occurring obstructions or unexpected conditions will be met when excavating dune sand. The excavation characteristics of dune sand are largely dependent upon the location of the ground water level. Dune sand has no clay binder, and as a result has no cohesive characteristics except for "apparent" cohesion which occurs when the sand is damp, but not saturated. If dry or saturated the sand may run or flow into excavations unless fully restrained. Under conditions of high seepage gradients below the ground water level, dune sand adjacent to even small openings in the shoring or earth support system will readily blow out and flow into the excavation.

When damp, dune sand possesses a weak "apparent" cohesion due to capillary action of the soil moisture. Damp dune sand may be rapidly excavated if support is immediately provided. Even under ideal conditions, standup time for dune sand is normally very short, depending on the size of the heading. Thus, damp dune sand is usually excavated by some sort of method offering continuous support such as breast-boards and forepoling, or shield driven. Open excavations are normally supported by continuous sheet piles or soldier piles and lagging.

Below the water table, excavation in dune sand can be carried out only if the seepage gradients toward the excavation are eliminated by advance

lowering of the water table, or if the seepage gradients are balanced by compressed air or a pressure-balancing tunneling machine such as a "slurry mole." Alternatively the soil could be rendered relatively impermeable by grouting or freezing, but these are expensive methods and could only be justified for localized critical problem areas. Dune sand is permeable enough to facilitate chemical grouting, if necessary.

The permeability of dune sand is relatively high (approximately $10^{-3}$ cm/sec), and the general absence of impermeable horizons suggests that conventional dewatering systems are usually a feasible and effective means of lowering the ground water level. Dune sand is relatively incompressible, and surface settlement from consolidation of dune sand due to a lowered water level is usually within acceptable limits.

The risk of surface subsidence due to loss of ground during tunneling operations in dune sand is usually high, unless special operations such as grouting are used. The amount of subsidence depends to a large degree upon the method of construction used and the degree of care and workmanship used by the excavation contractor. The following discussion of subsidence is based on reviews of case histories by others of tunneling projects in cohesionless sand (Peck, 1969; Peck et al., 1972).

The magnitude of surface subsidence resulting from loss of ground during tunneling operations depends primarily upon three factors: 1) the density of the overlying sand; 2) the depth of the tunnel below the ground surface; and 3) the tunneling method used. Assuming no extraordinary loss of ground occurs from a sudden run or flow of soil into the tunnel, conventional tunneling methods in cohesionless soils typically incur a loss of ground of from 0.5 percent to 1.0 percent of the tunnel volume. This loss of ground usually corresponds to approximately 1 to 2 inches of ground movement toward the tunnel crown. The degree to which this movement is transmitted to the ground surface depends upon the density of the sand and the depth of the tunnel (for a given tunnel diameter). In dense to very dense sands, the earth movement initiated by loss of ground into the tunnel will tend to be reduced or even absorbed altogether as the void progressively "stopes," or advances vertically toward the surface, because the relative density of the

displaced sand will be reduced slightly during movement. In very loose sand, it is possible that the relative density will be increased as stoping occurs, thereby amplifying the earth movement; however, as dune sand is generally dense, it is expected that the surface effect from any loss of ground at the tunnel will be reduced with increasing depth of the tunnel. At shallow depths (less than 2 diameters of cover), most of the movement will probably be transmitted to the ground surface, forming a shallow trough directly over the tunnel. Maximum settlement will occur at the center of this trough and taper off to zero settlement from one to two tunnel diameters on either side. At tunnel depths greater than 2 diameters the surface settlement will be less and the settlement trough shallower and wider. At greater depths (5 diameters or more), settlement at the ground surface may be negligible (again, assuming no extraordinary loss of ground occurs from a sudden run or flow of soil into the tunnel). The contractor's skill and workmanship play an important part in the amount of subsidence which might occur over the tunnel crown.

For special conditions, such as passing beneath a structure at shallow depths, where the expense can be justified, experience has shown that surface settlement can be successfully held to a very small amount by grouting the dune sand ahead of the tunnel from the working face or from the ground surface.

### 4.2.2 Colma Sand

The excavation characteristics of Colma sand are in many ways similar to dune sand. From the standpoint of stability, Colma sand is expected to be generally superior to dune sand because it is denser and often has an appreciable cohesion. From the standpoint of ground water control, however, Colma sand is expected to be more troublesome than dune sand.

Nowhere in the study area is it expected that Colma sand will be encountered above the ground water table. Tunneling in Colma sand below the water table is subject to the same restrictions as tunneling in dune sand: the ground water must be lowered to a level below the tunnel invert, or the seepage pressures must be balanced by compressed air or a pressure-balance type of tunneling method.

Colma sand is usually characterized by a variable amount of fines[*]. Thus, its permeability (from $10^{-3}$ to $10^{-6}$ cm/sec) is much more variable and generally lower than dune sand. Colma sand also exhibits well defined horizontal bedding with occasional impermeable (less than $10^{-6}$ cm/sec) horizons. In particular, the upper surface of the Colma Formation is usually very clayey for a thickness of several feet. For these reasons, it is our opinion that Colma sand would be difficult to dewater effectively. This is especially important when considering that much of the Colma sand encountered in the borings contains very few fines, and therefore is clean enough to react like dune sand in the presence of high seepage gradients at the tunnel heading.

Assuming fully controlled ground water, excavated openings in Colma sand are expected to be more stable than in dune sand. The variation of cohesion in the Colma Formation can not be adequately predicted on the basis of the widely spaced borings drilled for this study. At worst, excavation will require immediate full support as for dune sand; at best it will possess enough cohesion to be self-supporting for short periods. We recommend therefore, that tunneling operations in Colma sand be advanced in the same manner as used for dune sand, that is, shield-driven or fully supported by breastboards and forepoling.

Colma sand is relatively incompressible and is not expected to exibit significant consolidation settlement as a result of dewatering operations.

Subsidence due to loss of ground during tunneling operations will occur in Colma sand as for dune sand. Because Colma sand possesses varying degrees of cohesion, and because it is denser and will generally be excavated at a greater depth below the surface than dune sand, the settlement at the ground surface is expected to be somewhat less than for a similar excavation in dune sand. In some borings, notably Boring 26, discontinuous lenses of Colma sand were weakly cemented with iron oxide. Such cementation would strengthen the

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[*] Fines are defined as silt or clay sized particles passing a #200 sieve (0.08mm), about the smallest size that can be distinguished by the naked eye.

natural arching action over the tunnel crown and reduce the tendency for surface subsidence to occur as a result of lost ground during excavation.

Grouting Colma sand to render it impermeable would, in most instances, probably not be practical due to its moderate permeability. Compaction type grouting to prevent or correct surface subsidence could be carried out, however, as this method can be applied to nearly any soil.

### 4.2.3 Other Soil Deposits

Beach sand is not likely to be encountered anywhere in the study area except possibly near the Great Highway. The excavation characteristics of beach sand would be about the same as for dune sand. The most notable difference between dune and beach sand is the slightly coarser gradation and greater permeability (estimated at $10^{-2}$ cm/sec) of beach sand.

Marsh or lagoon deposits were encountered at several locations (Borings 1, 3, and 7) as a thin, dark green-brown or black clayey or silty layer on top of the Colma Formation. In our opinion, the deposits are infrequent and it is unlikely that extensive marsh deposits will be encountered. The marsh deposits occur as a very stiff overconsolidated clay and encountering this strata should present no significant excavation problems, although its presence may hamper dewatering efforts. The marsh deposits may be moderately compressible when loaded by dewatering the overlying soil, but in our opinion the magnitude of potential surface settlement would be small unless the stratum is much thicker than those encountered in the test borings.

Colluvium was encountered in many of the borings just over bedrock. Colluvium possesses adequate strength to be self-supporting for a moderate time and should not present any special excavation difficulties except that it may contain boulders. Consolidation settlement of colluvium due to dewatering the overlying soils is expected to be minor and have an insignificant impact upon surface structures.

Manmade fill soils in the study area are of no importance to this project except in two locations: the area of the former Playland-At-The Beach next to the Great Highway, and the embankment constructed for Lincoln Boulevard where it passes over Lobos Creek. No borings were drilled in either location for this investigation. It is probable that the primary

component of the fills is dune sand. Some debris and/or obstructions such as buried concrete footings might be present which could be a source of excavation difficulties. In particular, the embankment over Lobos Creek replaced an old concrete bridge and it is not known if the bridge footings were removed. The existing concrete box conduit for Lobos Creek would itself be an excavation problem requiring careful consideration.

Excavation in manmade fill, if composed of dune sand, would be subject to the same limitations discussed in Section 4.2.1. Subsidence and stability problems in fill soils would probably be more severe than for naturally occurring dune sand as the fill is likely to have a lower shear strength and density.

Mixed streambed deposits are believed to occur only at Lobos Creek, which is at approximately Elevation +27 feet. These deposits are probably sandy soils with gravelly and silty lenses and should be considered cohesionless and permeable. If the tunnel is constructed on the preferred route at an invert elevation of approximately +30 feet as recommended in Section 4.4.2, streambed deposits will probably not be encountered.

## 4.3 Excavation Characteristics of Bedrock

### 4.3.1 Great Valley Sandstone

The sandstone of the Great Valley Sequence is an excellent material for rock tunneling. Shear zones are infrequent and the rock is generally massive, fresh and very strong. Blasting will be required. The use of a boom excavator probably will not be feasible. The sandstone is not degraded by exposure to air or flowing ground water. Portions of the Mile Rock sewer tunnel were constructed in Great Valley sandstone and it was reported that ground water was not a serious problem (Taylor, 1916).

### 4.3.2 Great Valley Siltstone and Shale

The siltstone and shale of the Great Valley Sequence is only moderately strong and exibits a greater number of shear zones than the Great Valley sandstone. Unsheared shale may exibit some slight slaking or degradation upon exposure but not to a serious degree. Within shear zones the siltstone and shale is weak, highly brecciated, and slakes readily. Ground water is

not expected to be a major problem. Most of the existing Mile Rock sewer tunnel was driven through Great Valley siltstone and shale. Excavation could probably be carried out by blasting and/or with a boom excavator.

### 4.3.3 Franciscan Melange

The melange is expected to be the most difficult of the bedrock types to tunnel. The shaley matrix is very weak and it is our opinion that it may exhibit a tendency to squeeze into the excavation, and will exhibit raveling behavior in the tunnel crown and face. In contact with water the matrix slakes readily, and may swell when unrestrained. Laboratory tests indicate swelling pressures of up to 3,000 pounds per square foot may be developed if the sheared shale is fully restrained (Plate A-6), however deformations induced during excavation should result in a volume increase which will result in a correspondingly reduced swell pressure.

Within the shaley matrix, the melange zone contains tectonic inclusions of all of the other local Franciscan rock types: shale, graywacke, greenstone, serpentine, chert and limestone. These inclusions will be encountered in a random manner and may range from sand size to as much as several hundred feet across. Although the rocks making up these inclusions are generally more highly fractured than is the case outside of the melange zone, many are expected to be competent enough to require blasting for excavation. Blasting within the melange should be avoided to the extent possible as undesirable loosening of the shaley matrix may occur, resulting in excessive overbreak. In our opinion, very little ground water will be found in the melange zone since the sheared shale matrix is relatively impervious. If a very large inclusion of highly fractured rock is encountered it could be a source of ground water inflow, however the inclusions are generally of limited extent and should drain in a short time.

### 4.3.4 Franciscan Graywacke

The Franciscan graywacke is generally a reasonably competent rock for tunneling. Typically graywacke is moderately blocky and seamy. Excavation will require blasting. The graywacke is not susceptible to degradation by exposure to air or ground water. Clay-filled joints are common. Shear zones

in the graywacke are fairly common and at these locations the rock is typically highly brecciated and/or sheared. The graywacke is usually interbedded with shale and because of its lower strength, more shear zones are expected to occur in the shale than in the graywacke.

### 4.3.5 Franciscan Shale/Siltstone

During the subsurface explorations siltstone was encountered much less frequently than shale and as it is expected that the excavation properties of siltstone are generally similar to shale, the following discussion is applicable to both rock types.

As mentioned above, Franciscan shale is usually found interbedded with graywacke from thin partings to thick-bedded. Where unsheared, the shale is usually moderately strong. A boom excavator can be used in this material in lieu of blasting. Shale is commonly thinly laminated and fissile, so some raveling may be expected if the bedding orientation is unfavorable. (See Section 2.5 for a discussion of bedding and fracture orientation.) Some slight degradation or slaking may occur upon exposure to air and flowing ground water, but the effect is not expected to be rapid. Very often the shale is highly sheared and/or brecciated. Within shear zones, the shale is weak to very weak, is highly susceptible to slaking and raveling, and will probably be degraded by exposure to air and the inflow of ground water. Sheared shale is abundantly slickensided, and may be very slippery and sticky. During tunneling, care should be taken to ensure the stability of seemingly competent graywacke layers which may be bounded on both sides by sheared shale interbeds. In shear zones, the shale can probably be excavated with pneumatic spades. Blasting should be avoided in sheared material if possible.

### 4.3.6 Franciscan Greenstone/Chert

The Franciscan greenstone and chert are very hard, siliceous, and not susceptible to slaking, or degradation upon exposure. Of the two, chert is slightly harder than greenstone. None of the test borings encountered greenstone or chert in the massive state. Massive greenstone outcrops can be observed along the northern bluffs, however, and it is known that chert may be massive, albeit rarely. In outcrops and in the borings, chert was generally thin bedded and highly fractured. In the borings, greenstone was

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generally observed to be highly fractured or brecciated. Shear zones are common, and exibit some slickensides and clay filling. We expect that most of the chert and greenstone encountered will be fractured (RQD=0 or near 0*) to a degree permitting excavation by a boom excavator. This material will probably exhibit moderate raveling behavior and tend to drop blocks out of the tunnel crown. The 1938 Richmond-Sunset sewer tunnel was reported to have been driven through 2000 feet of "clay and red rock chert" and for several hundred feet was unsupported. This tunnel was horseshoe shaped and had a construction width of about 6 feet (Rothschild, 1938).

### 4.3.7 Franciscan Serpentine

Serpentine is generally highly sheared and very weak, with abundant slickensides. It can probably be excavated without blasting except for occasional unaltered and unsheared material which form very hard inclusions. Sheared material is subject to degradation upon exposure to air and flowing water and generally slakes readily.

## 4.4 Route Selection

### 4.4.1 The Route Selection Process

The route selection process was undertaken and analyzed by computer modeling as discussed in detail in Appendix B, and by engineering analysis considering cost and construction feasibility as discussed in Appendix C. As stated in Section 4.1, the primary criteria used for the route selection process considered 1) hydraulic constraints, 2) economy, and 3) construction risk.

For the various route corridors considered in the selection process, the location of the portals was fairly well defined by hydraulic requirements and the potential impact of construction activity at the tunnel portals was assessed to be about the same for each corridor. However, construction of the sewer under Lake Street could have a significantly greater impact on the neighborhood as compared with placing the eastern portal in the Lobos Creek area of the Presidio.

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*See Appendix A, Section A4.7 for a definition of RQD.

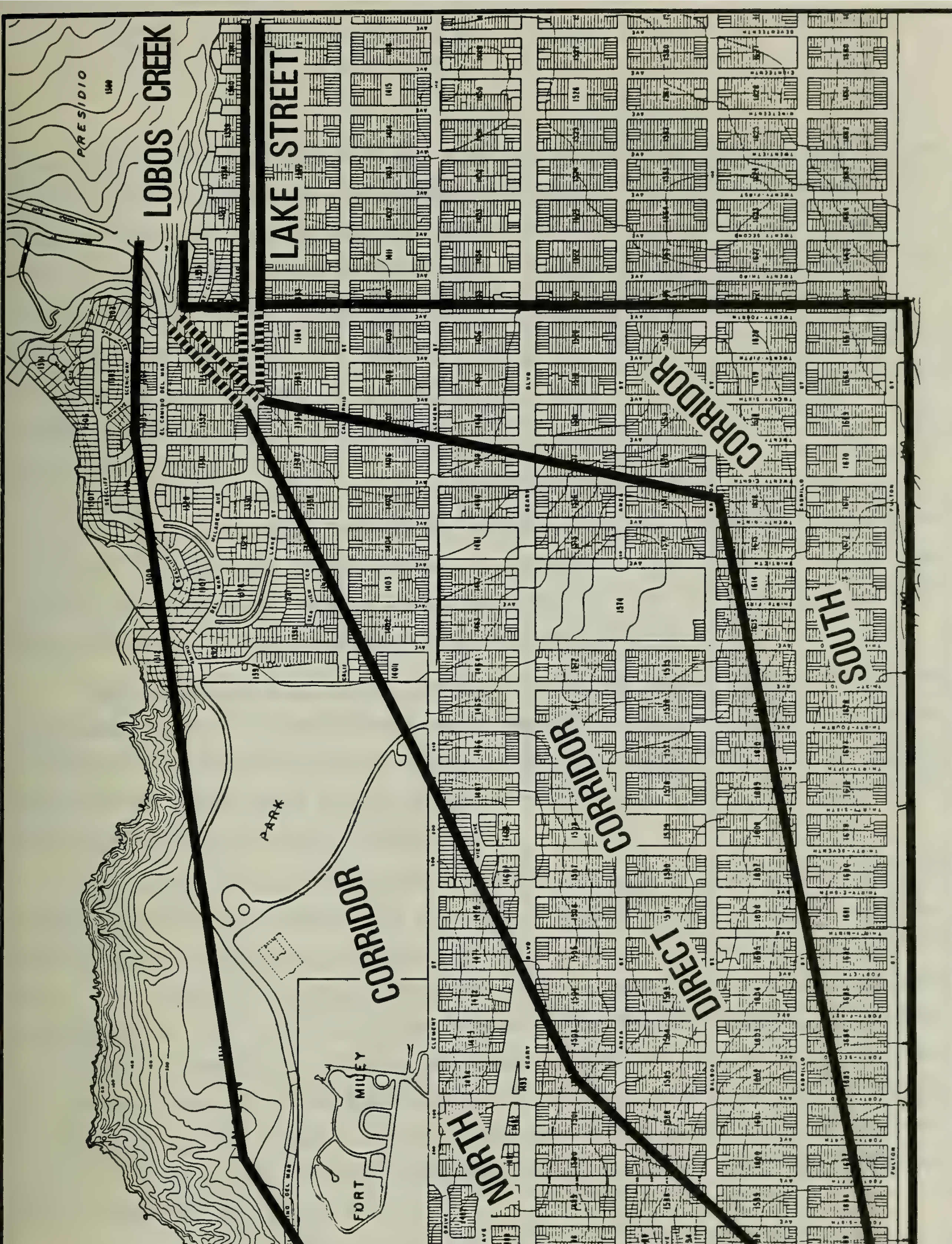
Considering the construction methods required for tunneling through the various soil, rock, and ground water conditions which are expected to be encountered in the study area, it was concluded that the ground water conditions would require an extensive dewatering program for construction of the tunnel in the sandy soils beneath the water table. Because of these ground water conditions, the relative cost for tunneling in sand would, for the most part, be greater than the cost for tunneling in rock (see Appendix C).

The potential effect of the sewer construction on property of the area is influenced to a large degree on the relative risk of ground movement over the tunnel crown during construction. As a general rule, the risk of ground movement decreases for tunnel construction at increasing depth below the surface, and the risk of ground movement is much less for construction in rock as compared to tunneling in soil. The potential effect of ground movement on surface features is, of course, reduced where the tunnel alignment is beneath parks, and to a lesser degree, where the alignment is beneath city streets, as opposed to construction beneath homes, businesses and public structures.

### 4.4.2 Route Corridors Considered

The study area was divided into three general route corridors, referred to in this study as the North, Direct, and South corridors as shown on Figure 1. Alignments in all three corridors would have the same starting and ending points; however, two different treatments for the east end were considered, each applicable to all three corridors.

The first scheme for the east end would have an extension of the existing sewer proceed under Lake Street from 17th Avenue to a point somewhere between 24th to 27th Avenue. This portion of the sewer could be either a mined tunnel, just below the existing sewers, or it could be constructed in open-cut, as discussed in Appendix C. Either method would replace the existing collector sewers under Lake Street. Somewhere between 24th and 27th Avenues a vertical drop shaft would be constructed to connect with the eastern end of the transport sewer tunnel. Either method considered for Lake Street would be relatively expensive, difficult and involve major



GENERAL ROUTE CORRIDORS CONSIDERED FOR THIS STUDY

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FIGURE 1

disruption to the residents of the area for an extended period of time. A mined tunnel would require extensive dewatering from the surface and two access shafts in Lake Street for the duration of construction. Open-cut construction would be from 30 to 50 feet deep, and would partially block the street, preventing two-way traffic in the construction zone.

The second scheme for the east end would have the sewer terminate in the Presidio near Lobos Creek, where the ground surface elevation is low enough to permit a direct-access portal without a drop-structure. This alternative would require that the transport tunnel be about 1,000 feet longer than if it ended at a drop structure under Lake Street, however this would be almost entirely offset by eliminating the drop shaft and reconstruction of the Lake Street sewer. A terminus in the Presidio would also provide the contractor with a larger staging area and would be considerably less disruptive to the residents of the Richmond District.

The basic distinguishing feature of each of the three general route corridors is that a North Route would maximize the portion of the tunnel constructed in bedrock; a South Route would be predominately a soil tunnel; and a Direct Route would be the shortest, constructed principally in soil but with as much as 2,500 feet through rock.

Plate 5A shows the location of 5 subsurface sections across the Richmond District. Plates 5B through 5G present the bedrock, soil and ground water conditions as interpolated between borings within the project area. The sections indicate the subsurface features in the three corridors considered in the route selection process. The Direct Corridor is depicted on Plate 5B, the South Corridor on Plates 5C and 5D, and the North Corridor on Plates 5E and 5F. The Preferred Route is shown by the subsurface section on Plate 5G. The general features and subsurface conditions for the corridors are discussed in the following three sections, with the Preferred Route discussed in section 4.4.3.

Appendix C, Construction Feasibility and Preliminary Cost Estimate, presents a detailed discussion of each route considering construction methods and relative costs. The route selection process by computer modeling is presented in detail in Appendix B, and considers the relationship of the

surface development and subsurface conditions, and presents the route having the best overall suitability for the factors considered.

#### 4.4.2.1 Direct Corridor

The Direct Corridor as indicated on Figure 1 traverses the heart of the western Richmond District residential area and represents the shortest alignment. However, any tunnel in the Direct Corridor would be mined principally in soil at depths of up to 150 feet below the surface, and as much a 60 feet below the ground water table. Plate 5B presents a typical alignment through this corridor and shows the soil and ground water conditions, as well as the bedrock which could make up more than 20 percent of the total overall alignment length of about 9,800 feet (to Lobos Creek).

Any tunnel alignment in the Direct Corridor would pass beneath a significant number of dwellings, which is a disadvantage in comparison with alignments in other corridors. In the western portion of this alignment the tunnel would be at shallow depths, which compounds the disadvantages by increasing the potential for adverse impact on surface features. The potential impact could be reduced by confining the sewer alignment to within the right-of-way of the city streets.

Further, it is considered a disadvantage to have a tunnel partially in soil and partially in rock, which would necessitate a complete change over in mining methods and equipment.

#### 4.4.2.2 South Corridor

Of the three corridors, the South Corridor represents the longest possible sewer alignment. As may be seen on Plates 5C and 5D the South Corridor does not have bedrock at an elevation which would intercept the tunnel grade, with the possible exception of a small area near Cabrillo Avenue and Twenty-fifth Avenue where the subsurface data indicates a somewhat higher rock surface elevation. Any tunnel alignment in this corridor would be mined entirely in soil, with the severe disadvantage of being far below the ground water surface.

#### 4.4.2.3 North Corridor

The possible tunnel alignments in the North Corridor would be mined principally in rock at considerable depths below the surface. Plates 5E and 5F depict the subsurface conditions within the North Corridor. These

sections illustrate the significant rock cover over the crown of any tunnel in the North Corridor, and also indicate the areas where the tunnel alignments would be in soil. This corridor also contains a large proportion of park and military reservation land with relatively few significant structures such as Fort Miley Veterans Hospital and the Palace of the Legion of Honor. The obvious advantage of this route is the low potential for surface distress because of the relatively good stability of a deep tunnel in rock and the relatively few inhabited structures overhead.

### 4.4.3 The Preferred Route

Route selection for the Transport Sewer was based upon the engineering criteria discussed in section 4.1. Using these criteria, and the route selection process outlined in section 4.4.1 and Appendices B and C, and based upon the information obtained during the three phases of this investigation, we have identified a Preferred Route, shown on the Site Plan, Plate 1.

The Preferred Route appears to be the best alternative from the standpoint of comparative cost and potential effects on surface structures and property. The studies presented in Appendix B, Route Selection by computer modeling (GIMS), and Appendix C, Construction Feasibility/Preliminary Cost Estimate, both concluded that the most suitable route for the tunnel should, where possible, be mined in rock rather than in soil, and should follow an alignment under undeveloped park land as opposed to residential areas.

Subsurface soil conditions and geologic conditions along the Preferred Route are shown on the interpretive Subsurface Sections, Plates 5G and 6C. Consideration of the environmental impact of the tunnel construction was beyond the scope of this investigation; however, it is our opinion that the environmental impact of the Preferred Route will compare favorably with that of alternative routes.

The Preferred Route is approximately 11,100 feet long. It may be divided into three parts based on the differences in subsurface conditions and construction methods. Plate 1 indicates the portions of the alignment for each of the three different types of construction, and they are described below:

A. Cut and cover in dune and beach sands

Beginning at the intersection of Fulton Street and the Great Highway, the sewer would run north for about 2,000 feet along the east edge of the Great Highway to a point near the steep bluffs on the south side of Sutro Heights Park. The ground surface elevation gently rises from about +12 feet at Fulton Street to about +20 feet at the northern end of the Great Highway, which is about 400 feet north of Balboa Street. This portion of the sewer would be entirely in dune or beach sands. Construction would probably be by conventional cut-and-cover methods. The water table may have to be lowered by several feet along this open excavation.

B. Tunneling in Rock

At the end of the cut-and-cover section, the sewer would make a right (northeasterly) turn and a tunnel portal constructed in rock at the base of the Sutro Heights bluffs. The bedrock surface slopes rather steeply in this area, thus the length of mixed-face conditions would be relatively short: possibly as short as 30 feet, depending on the specific location and diameter of the sewer.

From this point, the sewer would be excavated through bedrock in a straight line for about 7,900 feet to a point beneath El Camino del Mar, then turning right (easterly) again, the tunnel would transition from rock to soil beneath El Camino del Mar between 27th and 28th Avenues. All of the rock types described in this report are likely to be encountered with the possible exception of limestone. The ground surface elevation rises abruptly from about +20 feet at the Great Highway to over +160 feet in Sutro Heights Park. The ground surface then rises more gently to a maximum elevation of about +360 feet in Lincoln Park near the midpoint of the tunnel and then falls to about +115 feet at the east end of this part of the tunnel at El Camino del Mar.

At 48th Avenue about midway between Geary Boulevard and Anza Street, the sewer would pass over the Mile Rock Tunnel. At this point Mile Rock Tunnel has a crown elevation of +0.3 feet.

C. Tunneling in Soil

At El Camino del Mar, between 27th and 28th Avenues, the tunnel is expected to pass from rock to soil. Based on the estimated bedrock slope interpolated between Borings 26 and 31, the length of mixed-face conditions will probably be between 40 and 60 feet.

From this point, the sewer would be a tunnel excavated entirely in soil, about 1,200 feet long, running due east under El Camino del Mar and, upon reaching Lincoln Boulevard, curving slightly south to a portal adjacent to Lobos Creek in the Presidio. The ground surface elevation slopes downward from about +115 feet to +80 feet easterly along El Camino del Mar, dropping to about +35 feet at the portal area near Lobos Creek. Colluvium, dune sand and Colma sand would be encountered plus some manmade fill under Lincoln Boulevard. The water table would have to be lowered by 5 to 60 feet along this part of the tunnel during construction. At the Lobos Creek crossing, a modification of the existing creek conduit beneath Lincoln Boulevard would probably be necessary. The existing concrete box culvert at this point has an invert elevation about +26 feet and a crown elevation of about +32 feet.

## 4.5 Recommendations for Construction

### 4.5.1 Western Terminus - Construction in Open Cut

Regardless of the route chosen, construction of the sewer in the vicinity of the western end would probably be done in open cut since the ground surface elevation at Fulton Street and the Great Highway is only about +12 feet. Construction by open cut would be practical from Fulton Street to the base of the Sutro Heights bluffs, about 2,000 feet along the Preferred Route. For alternative alignments the length that could be constructed in open cut would depend upon the change in ground surface elevation and/or the nature of the surface usage; for instance an alignment in the Direct corridor would encounter existing residential housing within two blocks.

As shown on Plate 4, very little dewatering would be necessary along the Great Highway; somewhat more would be required for a route proceeding easterly along Fulton Street. In any case, the soils to be dewatered would be dune sand and a conventional dewatering system could be used.

### 4.5.2 Tunnel Excavated in Soil

Along the Preferred Route an excavated tunnel in soil would be needed from just east of Lobos Creek, under Lincoln Boulevard, and under El Camino del Mar to between 27th and 28th Avenues, a total of about 1,200 feet.

On the east side of the Lobos Creek culvert a portal would be constructed in or near the Lincoln Boulevard embankment. Depending upon the location of the portal, about the first 200 feet of tunnel would be through manmade fill. The nature of this fill is not known, but is probably primarily dune sand. Some boulders have been observed on the exterior slopes of this embankment, but it is not known whether or not boulders or other debris are included in the fill. Prior to construction of the embankment (construction drawing dated 1942) Lincoln Boulevard crossed Lobos Creek on a reinforced concrete bridge about 100 feet west of the present crossing. The bridge was demolished for construction of the embankment, but it is not known whether or not the bridge footings were removed. The footings are about 5 feet by 5 feet in size and if not removed during construction of the embankment several footings would probably be encountered by the tunnel excavation.

Beneath El Camino del Mar, the tunnel would be in dune sand for about 500 feet, then Colma sand for another 500 feet. Rock would be encountered between 27th and 28th Avenue, and it is expected that several feet of colluvium overlies the rock surface.

Along El Camino del Mar, dewatering may be accomplished by dewatering wells drilled from the ground surface. The number and spacing of wells will depend on the elevation of the tunnel. For an invert elevation of approximately +30 feet where the tunnel crosses Lobos Creek, the ground water would have to be drawn down about 5 feet to permit reconstruction of the creek culvert. From Lobos Creek westward the ground water would have to be drawn down by a steadily increasing amount as shown on the Subsurface Section, Plate 5G, ultimately requiring a maximum drawdown of about 60 feet at 28th Avenue.

For a southern route or the soil portions of a direct route, it is probable that a tunneling machine would be used. For the Preferred Route the

soil tunnel may be too short to justify mobilization of a tunneling machine, and it is more likely that the soil tunnel would be shield-driven or hand excavated using forepoling. Additional discussion of the construction feasibility of a direct route and south route is given in Appendix C. Both routes are considered uneconomical at this time due to the problem of controlling the ground water. It has been assumed in Appendix C that a combination of deep wells and compressed air inside the tunnel would be used for either route. An earth-pressure balanced type shield can, in theory, bore a soil tunnel without the need of lowering the ground water level. However, this type of machine has not been demonstrated under conditions involving more than 100 feet of head such as is the case for a south or direct route. For the direct route, dewatering from the surface would be particularly difficult since it would be necessary to occupy many private properties to set up an effective dewatering system.

It is recommended that, if a south route is adopted, the tunnel be centered under one of the avenues for the north-south portion and kept within Golden Gate Park for the east-west portion, thereby minimizing the risk of surface subsidence to private property. If a direct route is chosen, it will not be possible to avoid passing beneath private property. Along a direct route, there is insufficient depth of cover west of 44th Avenue to safely proceed under private properties without grouting or freezing the soil, therefore, if the direct route is chosen it is recommended that the alignment turn south at 44th Avenue and run to Golden Gate Park, and then west to the Great Highway.

### 4.5.3 Tunnel Excavated in Rock

As discussed in the Site Geology and the Excavation Characteristics, sections 2.5 and 4.2 respectively, the rock conditions will vary substantially along the Preferred Route alignment. While some of the more competent rock, such as the Great Valley sandstone, would be amenable to excavation by a full-faced tunnel boring machine, it is not considered feasible to use such a machine through the weaker material, particularly the melange. Thus the use of a tunnel boring machine for a northern route is not recommended.

On the other hand, the weaker material could, in part, be well suited to excavation by a boom excavator or pneumatic spades, as discussed in the

Excavation Characteristics section. In the melange zone it will be desirable, insofar as possible, to avoid excavation by blasting. In very weak material such as the melange, blasting could cause undesirable loosening of the surrounding rock, resulting in excessive overbreak and increased stability problems.

Disposal of spoil and ground water will present problems that are beyond the scope of this report. It should be borne in mind, however, that disposal of ground water collected by the tunnel may not be an insignificant problem. It is quite possible that water quality standards may not allow direct discharge to the ocean without treatment to reduce turbidity. Such a contingency should be provided for during project planning.

An important aspect of excavating the tunnel through rock will be the manner in which the contract and specifications are written. Because the ground support requirements are expected to vary considerably over short distances, it is recommended that a support system be specified which will be adaptable to changing conditions. It is imperative that an efficient construction monitoring program be incorporated into the contract documents to provide a basis for the decision-making process during the construction period.

It is recommended that a target-type of contract be used rather than a fixed-price type of contract. In addition we recommend that an independent consultant with broad contractor's experience in tunneling be engaged during preparation of the specifications and other contract documents.

## 4.6 Construction Monitoring

The following sections discuss the general types of construction monitoring recommended for this project. Specific recommendations for the monitoring systems can be provided during the final design stages.

### 4.6.1 Settlement Monitoring

Settlements will probably occur during tunneling construction in soil, and may also occur adjacent to open-cut construction in soil. The magnitude and locations of such settlement will depend on several factors such as soil type, construction procedures and workmanship, the amount of dewatering, the dimensions of the sewer and its depth below the ground surface.

The settlement survey program should be initiated well before the start of construction operations to obtain reliable baseline data. In addition, settlement readings should be continued after completion of the tunnel, as construction related settlements may occur a considerable time after the work is completed.

We recommend that at least two settlement markers be established on every structure that is within 100 feet of the sewer centerline where the tunnel is in or near soil. If the northern portal is located near Lobos Creek, it may be desirable to monitor the homes between Lobos Creek and West Clay Street as well, since this area is currently subject to slope creep and any existing structural damage should be well documented.

When the settlement marks are established, a careful crack survey should be made of each structure as well. If the Preferred Alignment is chosen, particular care should be taken with this crack survey for homes along El Camino del Mar between 29th and 31st Avenues, as well as on West Clay Street as previously noted. Additional settlement marks should be placed on nearby structures where difficult construction conditions are expected. These areas of difficult construction include transition zones from rock to soil, the portal areas, and areas where the tunnel is at shallow depths below the ground surface.

In addition to settlement marks on nearby structures, a series of marks on the ground surface should be established at 100 foot spacing along the sewer centerline and 50 feet to either side where the tunnel is located in soil beneath the streets or private property. Markers are not recommended where the alignment is in rock or under park land. For open cut with a braced excavation, the shoring should be monitored for vertical and lateral movement.

### 4.6.2 Ground Water Monitoring

Where dewatering is required, the ground water level should be monitored to determine the water level along the sewer alignment and in areas adjacent to the construction. This monitoring program should include installation of simple standpipe piezometers, and provisions for reading and evaluation of results. The water discharged from the wells should also be monitored to ensure that fine-gained soils are not being removed.

### 4.6.3 Geology and Ground Support System Monitoring

It is strongly recommended that a full-time engineering geologist be made part of the resident engineer's staff for a continuous and daily logging of geological conditions as encountered during construction. This log may be useful for anticipating subsurface conditions ahead of the excavation and may also be made part of the contractual basis from which payment to the contractor is determined.

The engineering geologist should also be responsible for monitoring the ground-support system interaction. In addition to visual observations, it will be necessary to monitor this interaction by a reasonable instrumentation program. This program should include tape extensometer points to measure closure, and weldable strain gauges on steel members in critical areas.

### 4.6.4 Monitoring of Ground Vibrations

Rock blasting may produce undesirable ground vibrations above or at some distance from the construction area. While it is our opinion that ground vibrations will not be a serious problem, we recommend that vibration levels be monitored at the surface when blasting beneath or near residential private property, hospitals, or schools. If necessary, the contractor's blasting program may have to be modified locally if the vibration levels measured prove to be excessively high.

### 4.6.5 Monitoring for Subterranean Gases

No direct evidence of subterranean gases was found in any of the test borings and it is our opinion that the probability of encountering naturally-occurring toxic or explosive gases during excavation is very small. Trace quantities of an unidentified black "oily appearing" substance were encountered in several instances while drilling Franciscan shale. We have had a series of analytical tests performed on this substance in an attempt to determine if it is petro-chemical or inorganic. The results of these tests, presented on Plate A-7, are open to interpretation. It is our opinion, based upon the physical appearance, the high volatile percentage (at 500°C), the carbon/hydrogen content, and the apparent lack of crystalline structure, that the substance is probably organic. It was observed only in very minute quantities, however, and had no apparent odor. Considering these factors, we feel it is unlikely that this substance is indicative of hazardous gassy conditions.

A greater possibility of gaseous conditions probably exists from manmade sources such as leaking natural gas pipes or service stations, but this too we consider relatively unlikely. For purposes of classifying ground conditions for Cal-OSHA* requirements, it is our opinion that the site should be classified as "potentially gassy", primarily due to its urban location rather than its geology. This classification will require that gas detectors be placed in the tunnel and other precautions may be required by code.

## 4.7 Recommendations for Further Studies

Further explorations would be desirable before final design recommendations are made regarding the route selected. Depending upon the route finally selected, one or more of the following areas should be investigated further.

Great Highway - It is recommended that several shallow borings be drilled along the Great Highway north of Fulton Street to obtain information on the in-situ densities of the soil and to monitor ground water levels. In addition, subsurface conditions in the immediate portal area of the Preferred Route at the base of the Sutro Heights bluffs are not yet well-defined. An earlier study was conducted by others for a proposed development for the former Playland-At-The-Beach area, and we recommend that the City obtain this information (Lee and Praszker, 1972).

Preferred Route - At least 4 and preferably 6 deep borings are recommended along the Preferred Route to better define geologic conditions at certain locations in Lincoln Park, the Seacliff neighborhood and the area near Clement and 39th Avenue. These borings may result in adjustments to the location of the Preferred Route.

Southern Route - If a southern route is selected, it will be important to confirm that bedrock will not be encountered. For this reason at least one boring would be needed in the vicinity of 26th Avenue and Cabrillo Street, where present information indicates rock may be near invert level.

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*California Administrative Code, Title VIII, Industrial Relations; Division of Industrial Safety, Tunnel Safety Orders, Section 8422.

Lobos Creek - To the best of our knowledge, there is no subsurface data on the Lobos Creek area. If this alternate portal area is selected, several borings will be needed to adequately define subsurface conditions. In particular, borings are needed in Lincoln Boulevard to determine the composition of the fill embankment over Lobos Creek. As mentioned before this embankment may contain large obstructions left behind from the former concrete bridge which spanned Lobos Creek.

Direct Route - If a direct route is selected, additional borings will be needed to determine more precisely where the tunnel will enter and leave bedrock and the type of bedrock present.

El Camino del Mar - Additional borings will be needed near the northwesternmost corner of Block 1331 to better define the subsurface conditions where the transition from soil to bedrock is expected.

Pump Tests - Depending upon the location of the final alignment, an extensive dewatering program will probably be required. We recommend that a series of pump tests be conducted as an aid to design of an effective dewatering system.

Any final alignment selected which differs from those specifically investigated by this report will require further studies. While we do not expect subsurface conditions anywhere in the study area to be markedly different from the conditions described in this report, it will be necessary to confirm this as well as to determine the locations at which the tunnel will pass from one soil or rock type to another. Final recommendations for further study must wait until a final sewer alignment is chosen.

## 5.0 CONCLUSIONS

### 5.1 Preferred Route Alignment

It is our opinion, based on the results of the geotechnical investigation and route selection study, that it is feasible to construct the proposed Richmond Transport Sewer, and that the Preferred Route presents the least potential construction impact on the residents and facilities of the Richmond District. The investigation, analyses, and route selection study show the Preferred Route through the Northern Corridor with the eastern terminus at the Lobos Creek area of the Presidio to be the most beneficial with respect to cost, engineering and construction feasibility.

The overall length of the sewer along the Preferred Route would be about 11,100 feet. The principal engineering feature of this route is construction of a 9,100 foot long tunnel of which about 7,900 feet will be in rock and about 1,200 feet in soil. The sewer would pass under the Sutro Heights Park, Lincoln Park, and the Seacliff area as shown on Plate 1. In the Seacliff area, where the tunnel transitions from rock into soil, the Preferred Alignment runs beneath El Camino del Mar, with the portal at the Lobos Creek area of the Presidio. The western portion of the route, about 2,000 feet, would be cut-and-cover construction along the Great Highway with the tunnel portal located in the base of the bluffs at Sutro Heights Park.

Subsequent review and environmental impact studies must be completed before the design alignment can be finalized. These studies may indicate that adjustment or modification of the Preferred Route is necessary; however, it is the conclusion of this study that a final alignment is unlikely to be chosen through the direct or southern corridors.

The following Plates and Appendices are attached and complete this report.

| | |
|---|---|
| Plate 1 | Site Plan With Preferred Tunnel Route |
| Plate 2 | Bedrock Surface Contours |
| Plate 3 | Bottom of Dune Sand Contours |
| Plate 4 | Contours of Estimated Ground Water Surface |

Plate 5A Location of Subsurface Sections

Plate 5B Sub-Surface Section, Section F-B Direct

Plate 5C Sub-Surface Section, Section F-E Fulton Street

Plate 5D Sub-Surface Section, Section E-C 26th Avenue

Plate 5E Sub-Surface Section, Section D-A, Lincoln Park - Lake Street

Plate 5F Sub-Surface Section, Section F-D, 48th Avenue - Lincoln Park

Plate 5G Subsurface Profile Along Preferred Route

Plate 6A Geologic Map of Western Richmond District

Plate 6B Generalized Geology at Tunnel Invert Level

Plate 6C Interpretive Cross Section of Bedrock Geology Along Preferred Tunnel Route

Plate 7A Rose Diagram of Bedding in Graywacke West of Phelan Beach

Plate 7B Rose Diagram of Faults, Fractures and Shear Zones in Graywacke West of Phelan Beach

Plate 7C Rose Diagram of Bedding in Graywacke East of Phelan Beach

Plate 7D Rose Diagram of Faults, Fractures and Shear Zones in Graywacke East of Phelan Beach

Plate 8 Major Active or Potentially Active Faults in the San Francisco Bay Area

Plate 9 Reported Epicentral Locations (1808-1976)

Plate 10A Exceedance Probabilities: Soil Equation

Plate 10B Exceedance Probabilities: Rock Equation

Plate 11 Results of the One-Dimensional Soil Column Analysis

| | |
|---|---|
| Plate 12A | Liquefaction Potential and Normalized Penetration Resistance Values for the Great Highway Area |
| Plate 12B | Liquefaction Potential and Normalized Penetration Resistance Values for Fulton Street/North Golden Gate Park Area |
| Appendix A | Subsurface Soil and Rock Types; Field Explorations and Laboratory Testing |
| Appendix B | Route Selection by Computer Modeling (GIMS) |
| Appendix C | Construction Feasibility and Preliminary Cost Estimates |
| Appendix D | Seismic Analyses |

Respectfully Submitted,

DAMES & MOORE

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Partner

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Job No. 185-131
March 9, 1979

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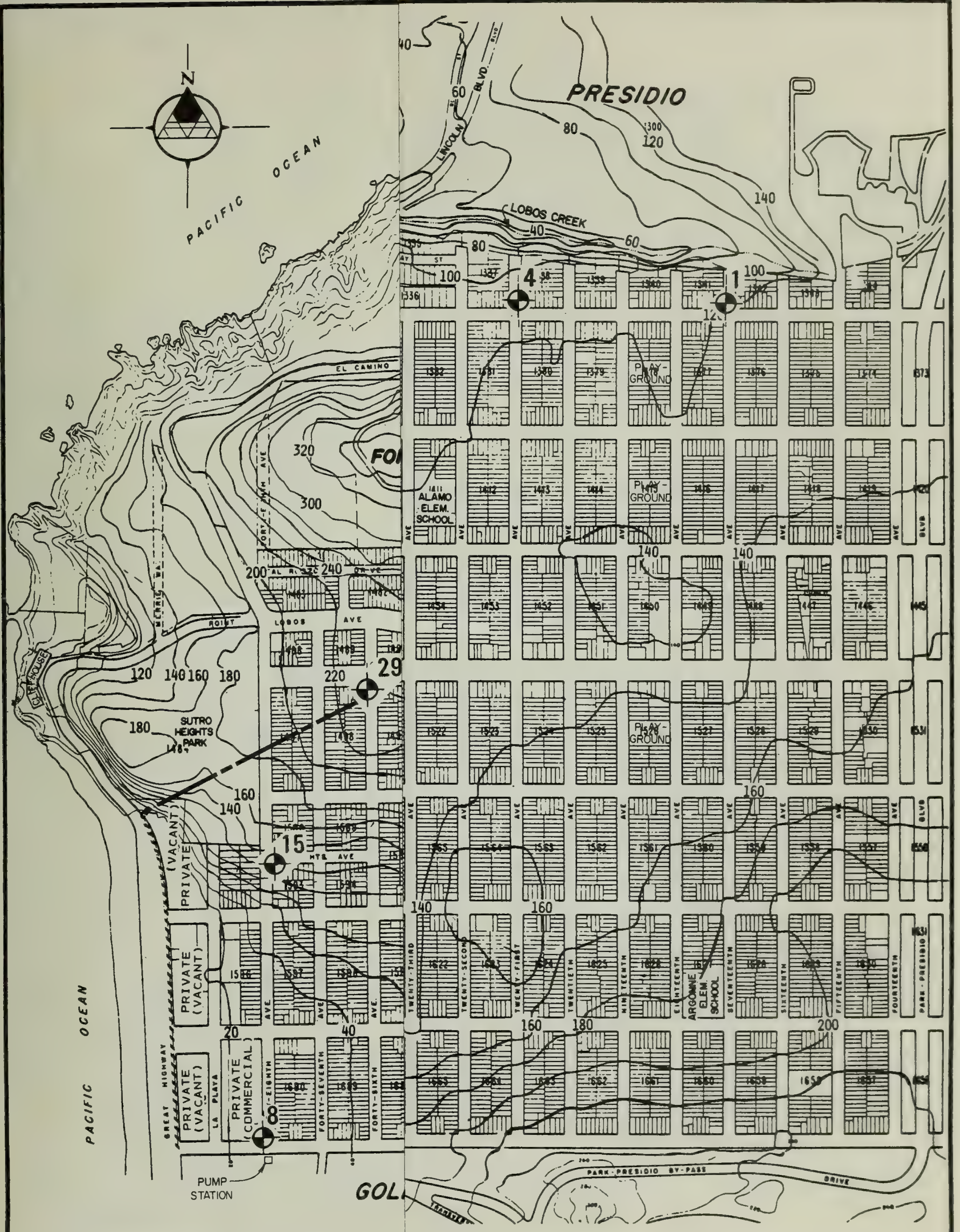

| REVISIONS | | | |
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| DESCRIPTION | DATE | BY | CK BY |
| Preliminary | 04/78 | MWS | WCW |
| Contours Added, Revised | 06/01/78 | MWS | WCW |
| Contours Revised | 07/20/78 | MWS | MWS |
| contours Revised | 10/13/78 | MWS | MWS |
| PREFERRED ROUTE, BORINGS ADDED | 11/08/78 | MWS | WCW |

# SITE PLAN WITH PREFERRED TUNNEL ROUTE

FEET

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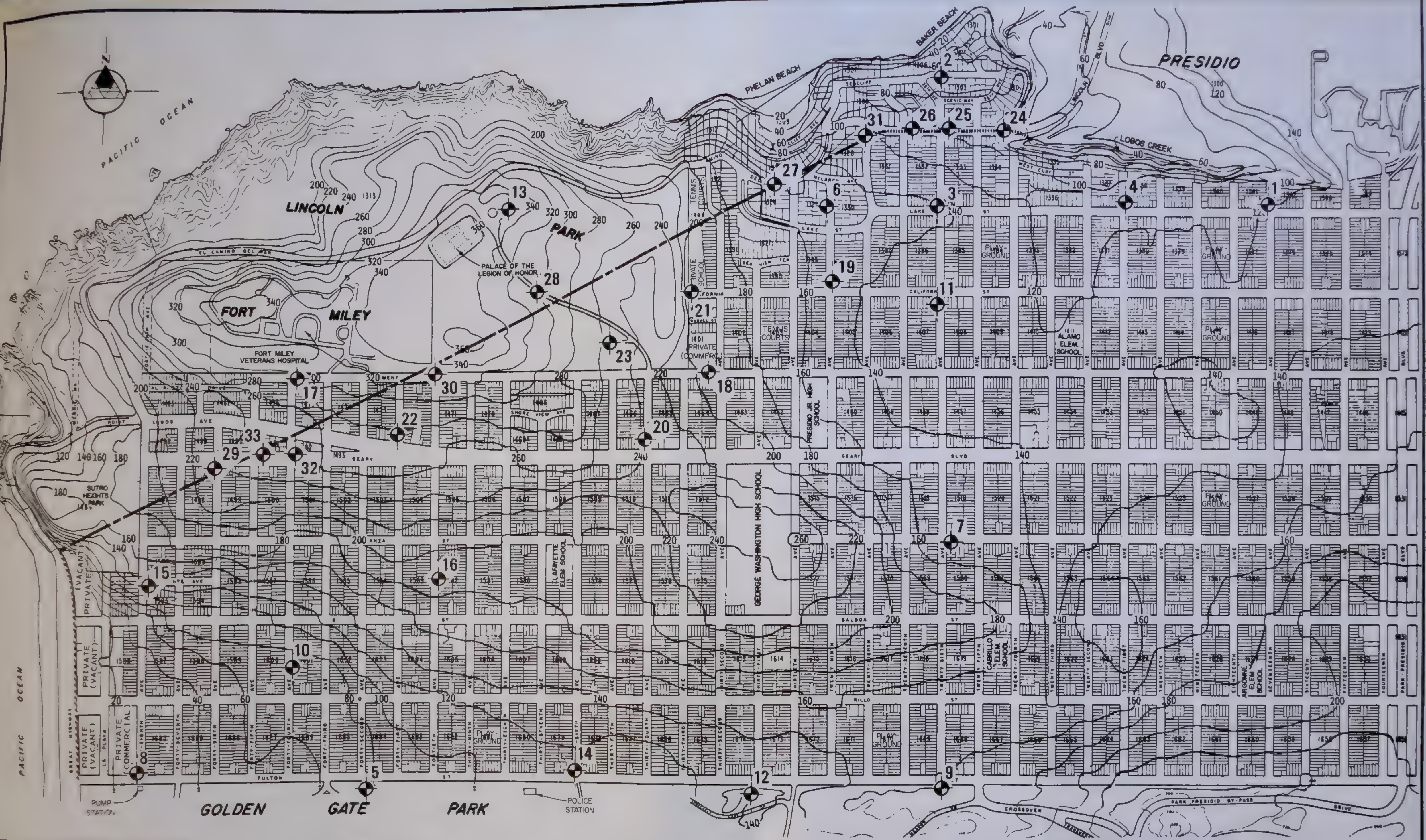
**DAMES & MOORE**

PLATE 1



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| Contours Revised | 07/20/78 | MWS | MWS |
| Contours Revised | 9/13/78 | MWS | MWS |
| Preferred Route, Borings Added | 11/28/78 | MWS | WCW |

KEY: PREFERRED ROUTE

- CUT AND COVER TUNNEL
- MINED ROCK TUNNEL
- MINED SOIL TUNNEL
- ⊕ BORINGS DRILLED FOR THIS INVESTIGATION

NOTES:
1) CONTOURS ARE GROUND SURFACE ELEVATION BASED ON OFFICIAL CITY GRADE
2) DATUM USED IS CITY AND COUNTY OF SAN FRANCISCO (0 = MSL + 8.616 FEET)

# SITE PLAN WITH PREFERRED TUNNEL ROUTE

FEET
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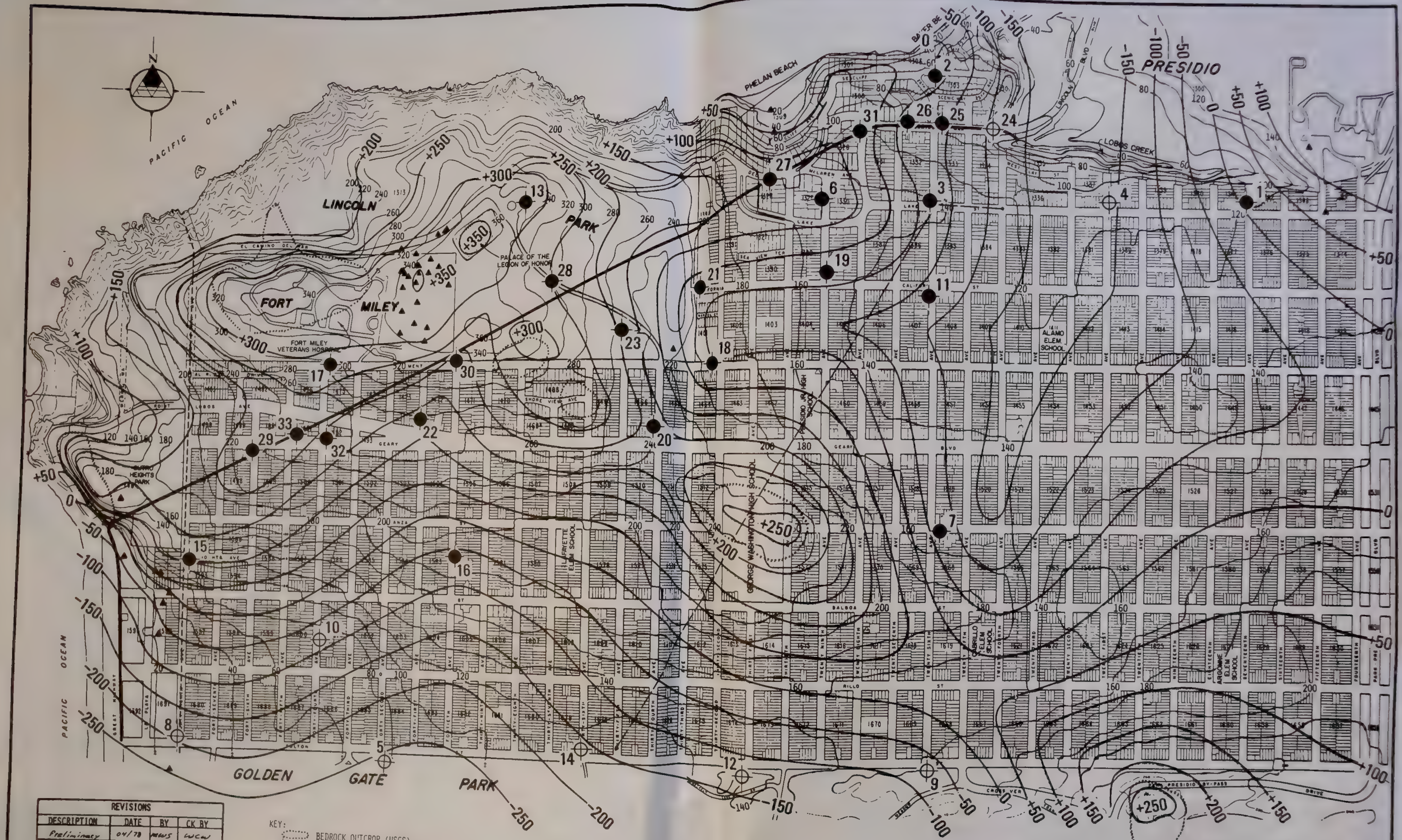
DAMES & MOORE

PLATE 1



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| Contours Added, Revised | 06/01/78 | MWS | WCW |
| Contours Revised | 07/20/78 | MWS | MWS |
| Contours Revised | 10/13/78 | MWS | MWS |
| DATA POINTS ADDED CONTOURS REVISED | 11/1/78 | MWS | EJM |

KEY:
- BEDROCK OUTCROP (USGS)
- 2 ● D&M BORING WHICH REACHED BEDROCK
- 2 ⊕ D&M BORING WHICH DID NOT REACH BEDROCK
- ▲ BORING BY OTHERS WHICH REACHED BEDROCK
- △ BORING BY OTHERS WHICH DID NOT REACH BEDROCK
- BORING NUMBER
- LOCATION OF 1938 SEWER TUNNEL & CONSTRUCTION SHAFTS
- MILE ROCK SEWER TUNNEL (CONST. 1914-1916)
- LOCATION OF PREFERRED TUNNEL ROUTE

NOTES:
1) CONTOURS ARE BASED ON LIMITED DATA AND ARE SUBJECT TO REVISION CONDITIONS IN THE FIELD MAY DIFFER FROM THAT SHOWN ABOVE.
2) DATUM USED IS CITY & COUNTY OF SAN FRANCISCO DATUM
3) DARK CONTOURS ARE TOP OF BEDROCK
4) LIGHT CONTOURS ARE OFFICIAL GRADE

# BEDROCK SURFACE CONTOURS

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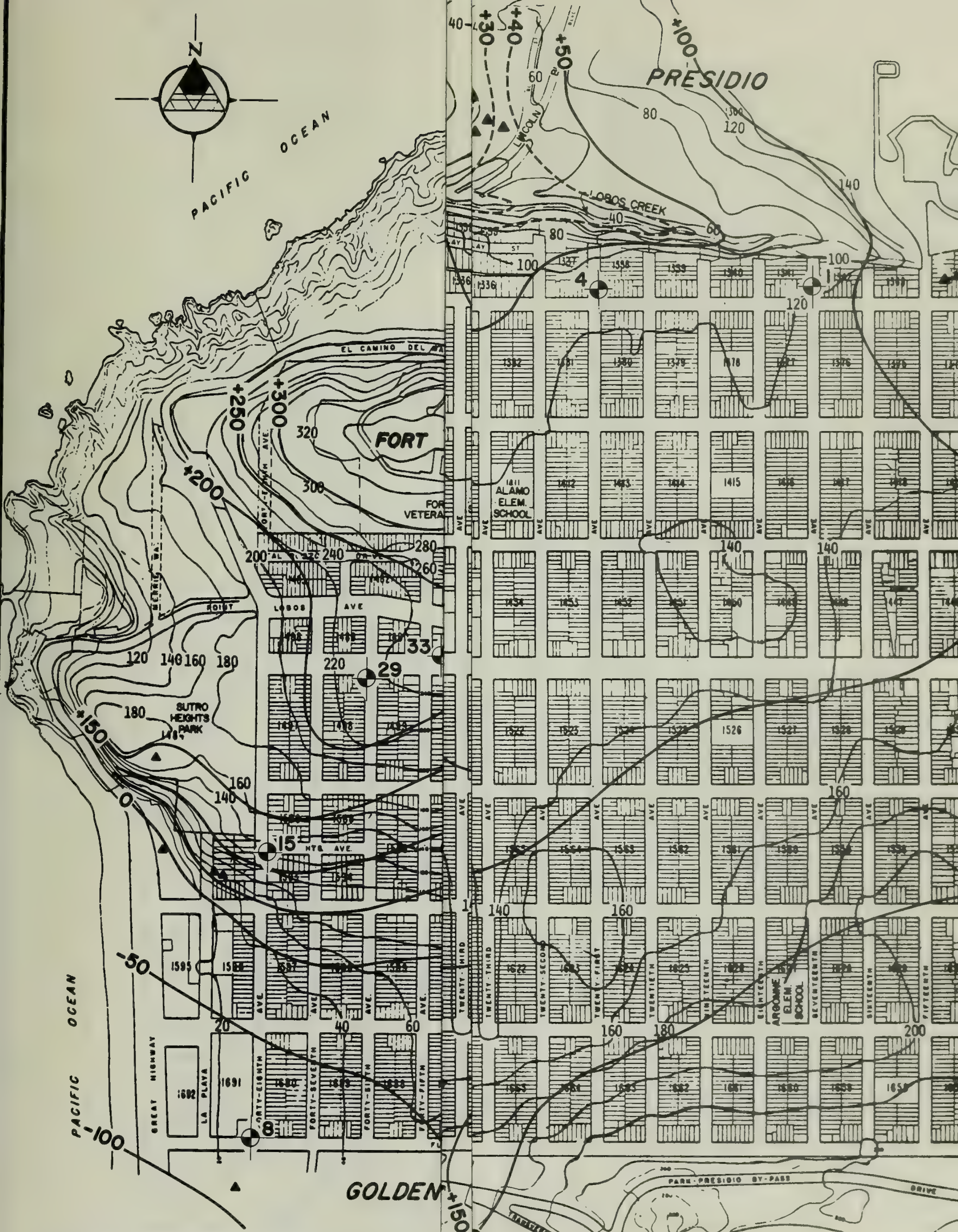
DAMES & MOORE

PLATE 2



# CONTOURS OF ESTIMATED GROUND WATER SURFACE

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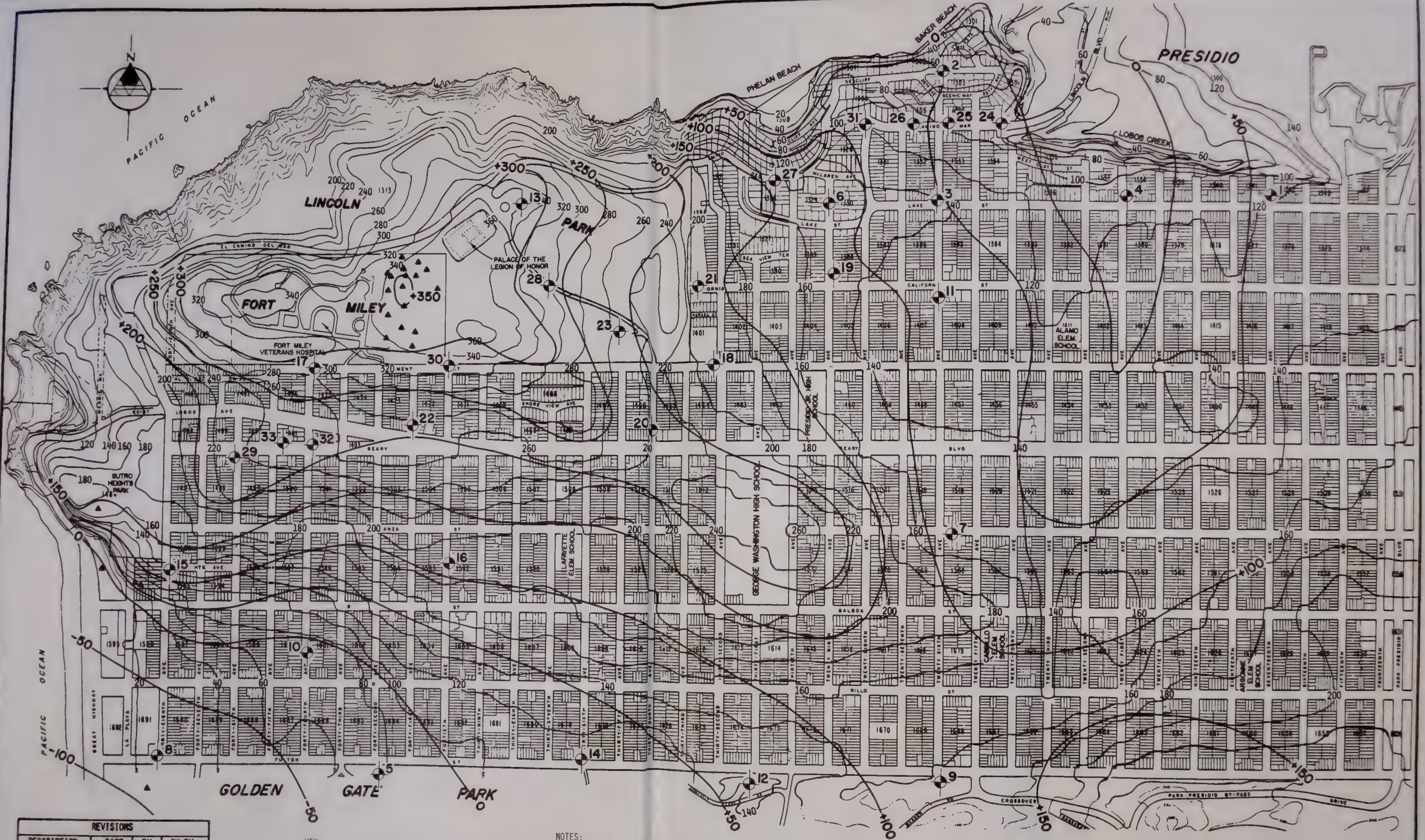
| Contours Revised | 07/20/78 | mws | mws |
| contours Revised | 10/13/78 | mws | mws |
| Phase III, Final | 12/10/78 | mws | wcw |

DAMES & M

PLATE



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| Contours Revised | 07/20/78 | MWS | MWS |
| Contours Revised | 10/13/78 | MWS | MWS |
| Phase II Final | 12/10/78 | MWS | WCW |

KEY:

+50 ELEVATION CONTOUR BOTTOM OF DUNE SAND

▲ BORINGS DRILLED BY OTHERS

60 CONTOUR, GROUND SURFACE ELEVATION

⊕ BORINGS DRILLED FOR THIS INVESTIGATION

NOTES:

1) CONTOURS ARE BASED ON LIMITED DATA AND ARE SUBJECT TO REVISION. CONDITIONS IN THE FIELD MAY DIFFER FROM THAT SHOWN ABOVE.
2) GROUND SURFACE CONTOURS ARE BASED UPON OFFICIAL CITY GRADE.
3) DATUM USED IS CITY & COUNTY OF SAN FRANCISCO (0 = MSL + 8.616 FEET)

# BOTTOM OF DUNE SAND CONTOURS

FEET
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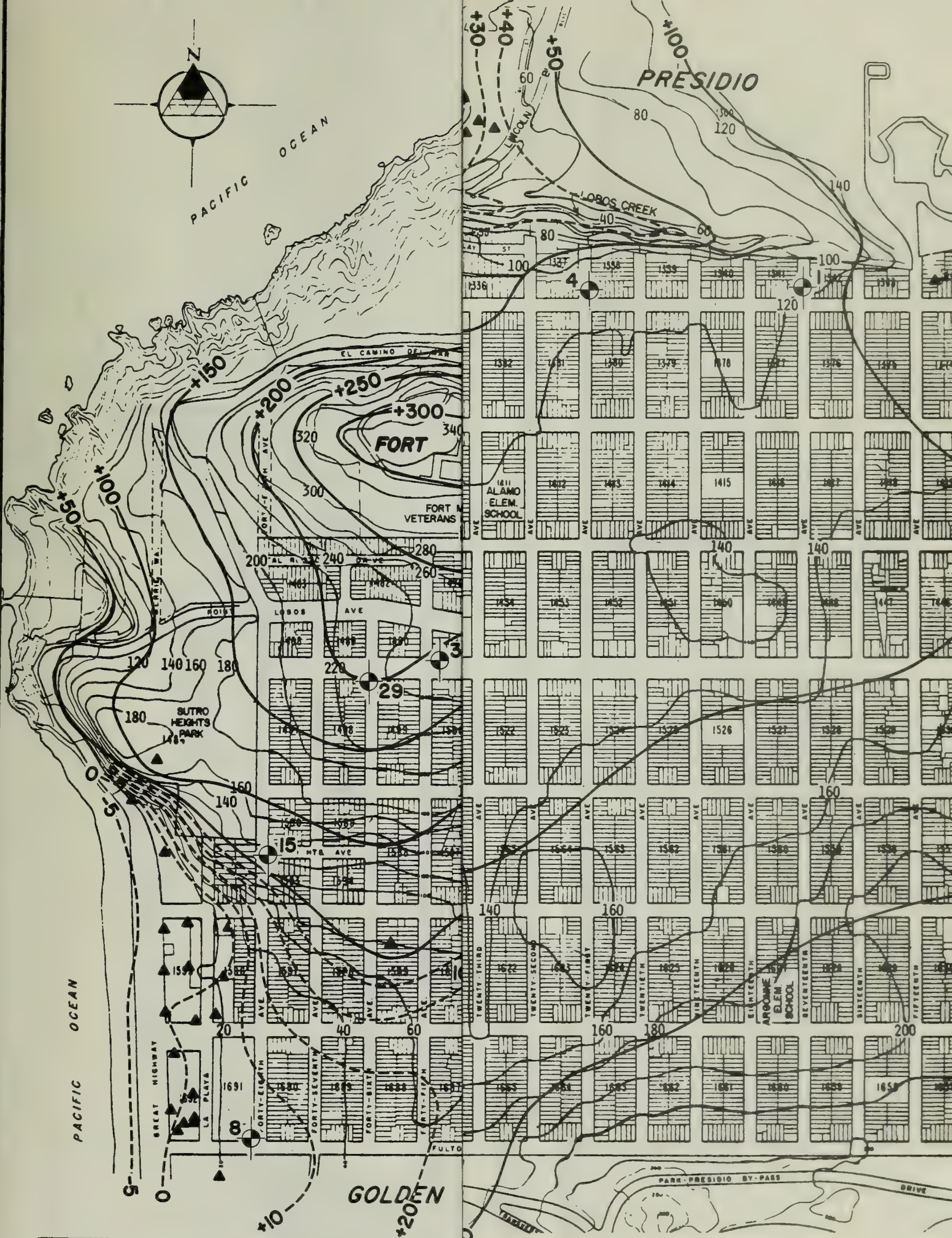
DAMES & MOORE

PLATE 3



| REVISIONS | | | |
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| DESCRIPTION | DATE | BY | CK BY |
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| Contours Added, Revised | 06/01/78 | MWS | WCW |
| Contours Revised | 07/20/78 | MWS | MWS |
| Contours Revised | 10/13/78 | MWS | MA |
| PHASE III, Final | 12/14/78 | MWB | WCW |

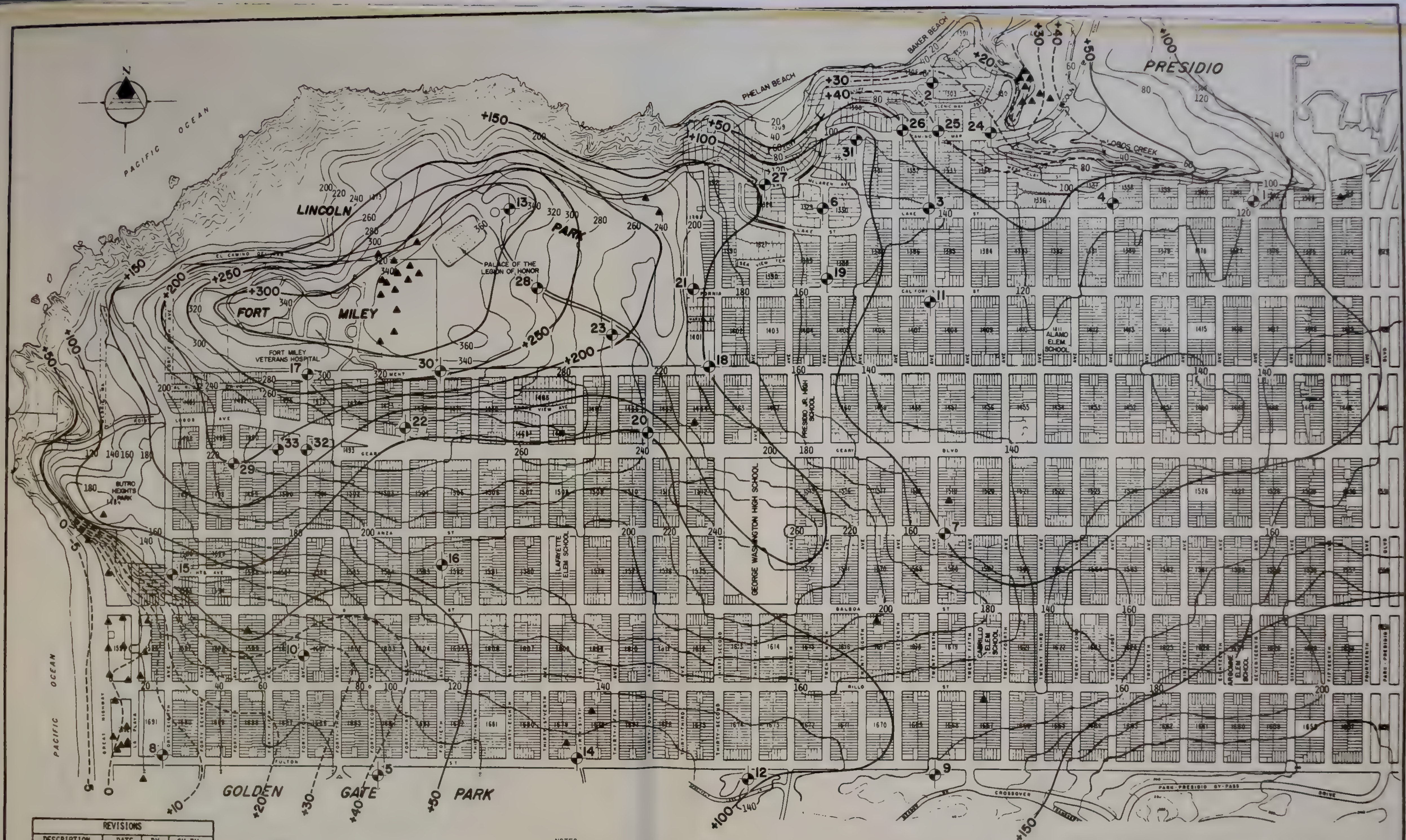
KEY:
+50
+10
60

# CONTOURS OF ESTIMATED GROUND WATER SURFACE

FEET
500 0 500 1000

DAMES & M

PLATE 4



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| Contours Revised | 07/20/78 | MWS | MWS |
| [illegible] | [illegible] | MWS | [illegible] |
| PHASE III Final | 12/14/78 | MWS | WCW |

KEY:

+50 ——— GROUND WATER ELEVATION CONTOURS.
+10 - - - INTERMEDIATE GROUND WATER CONTOURS.
——— GROUND SURFACE CONTOURS.
⊕ BORINGS DRILLED FOR THIS INVESTIGATION.
▲ LOCATION OF OLD WELLS WITH RECORDED GROUND WATER LEVELS AND BORINGS DRILLED BY OTHERS.

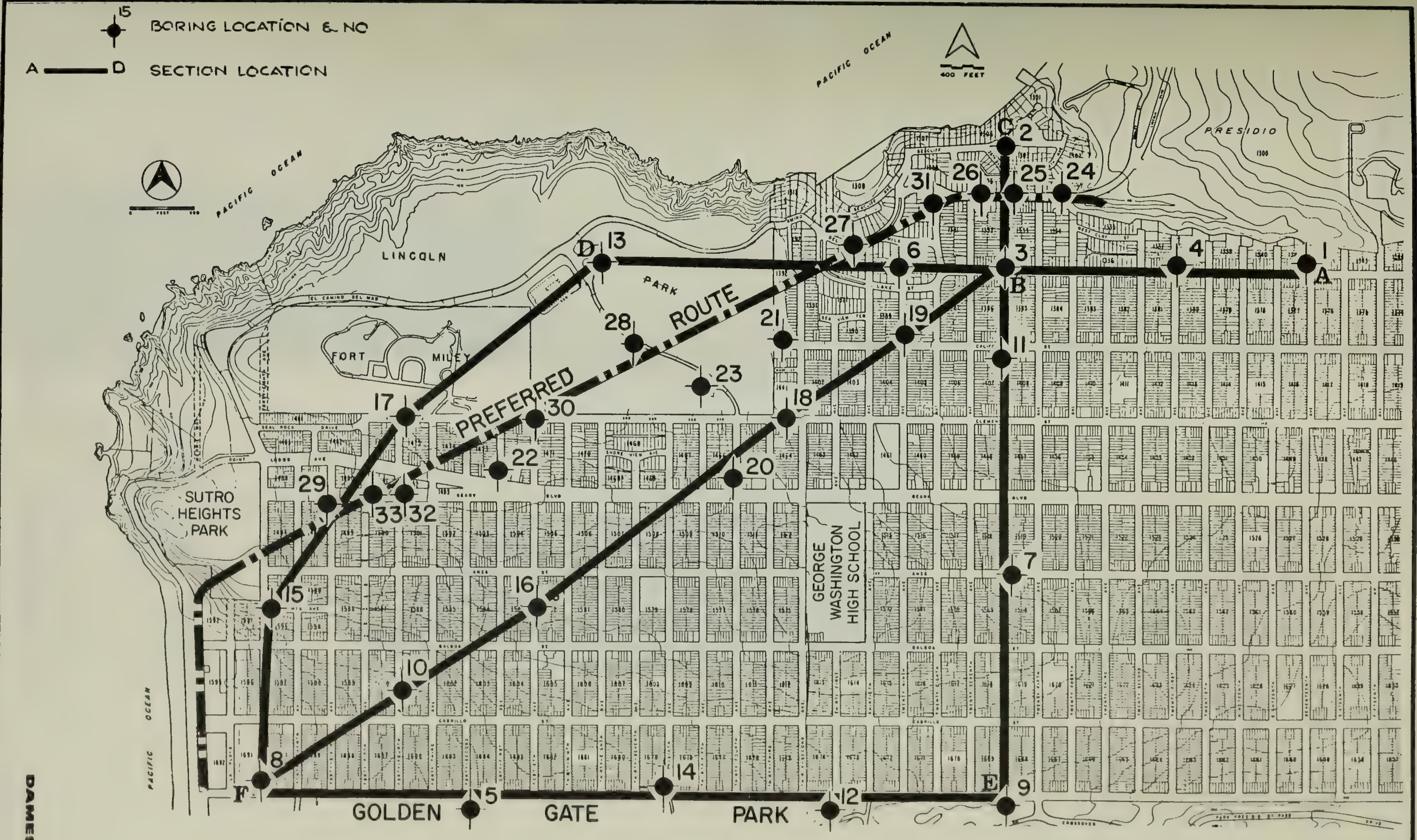
NOTES:
1) CONTOURS ARE BASED ON LIMITED DATA AND ARE SUBJECT TO REVISION. CONDITIONS IN THE FIELD MAY DIFFER FROM THAT SHOWN ABOVE
2) GROUND WATER ELEVATIONS SHOWN ARE BASED ON HISTORICAL WELL DATA AND WATER LEVELS MEASURED IN THE BORINGS
3) DATUM USED IS CITY AND COUNTY OF SAN FRANCISCO (0 = MSL + 8,616 FEET)
4) A LOW PIEZOMETRIC LEVEL HAS BEEN RECORDED IN BORING 13. SEE TEXT FOR EXPLANATION.

# CONTOURS OF ESTIMATED GROUND WATER SURFACE

FEET
500 0 500 1000

DAMES & MOORE

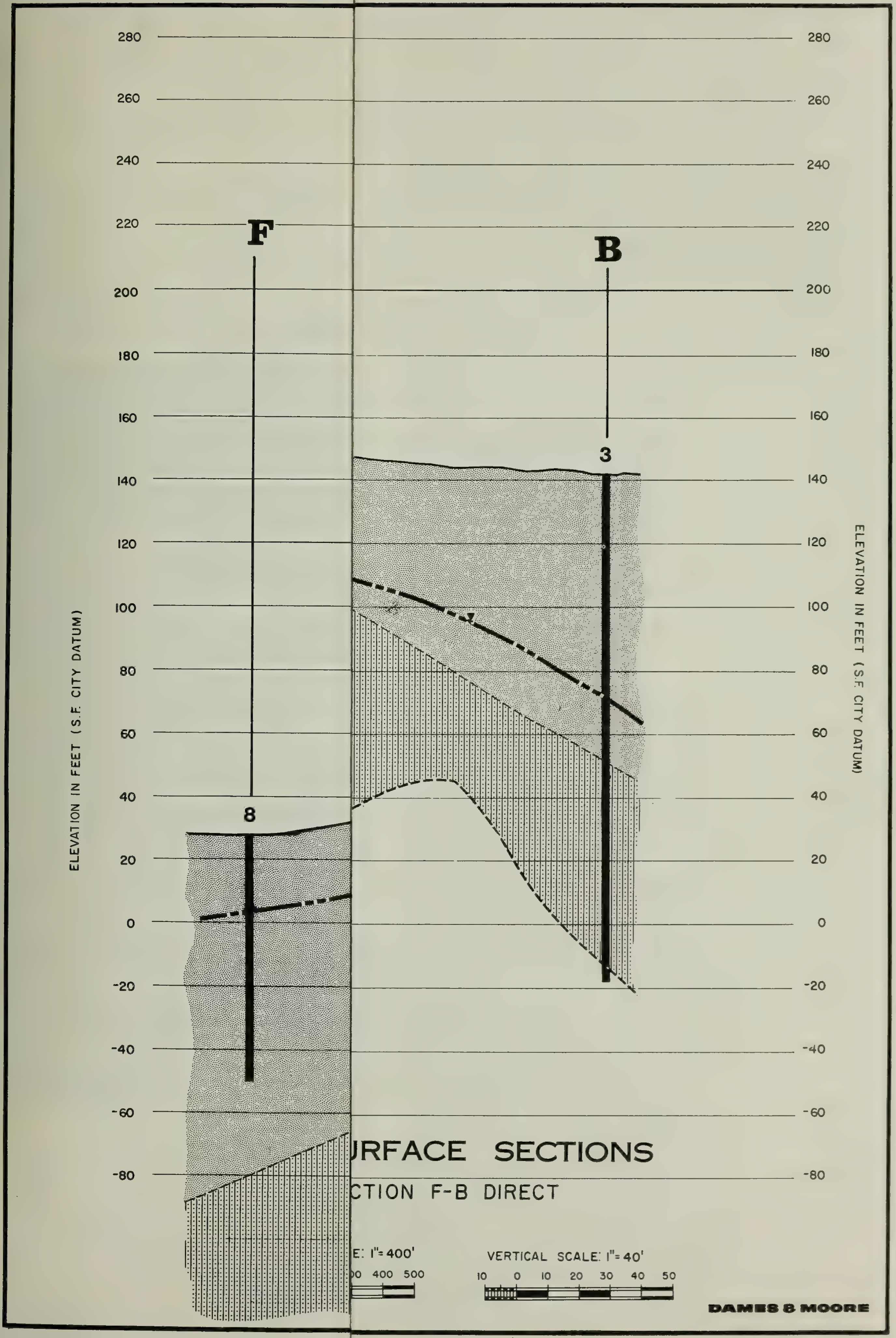
PLATE 4



## LOCATION OF SUBSURFACE SECTIONS

**DAMES & MOORE**

PLATE 5A

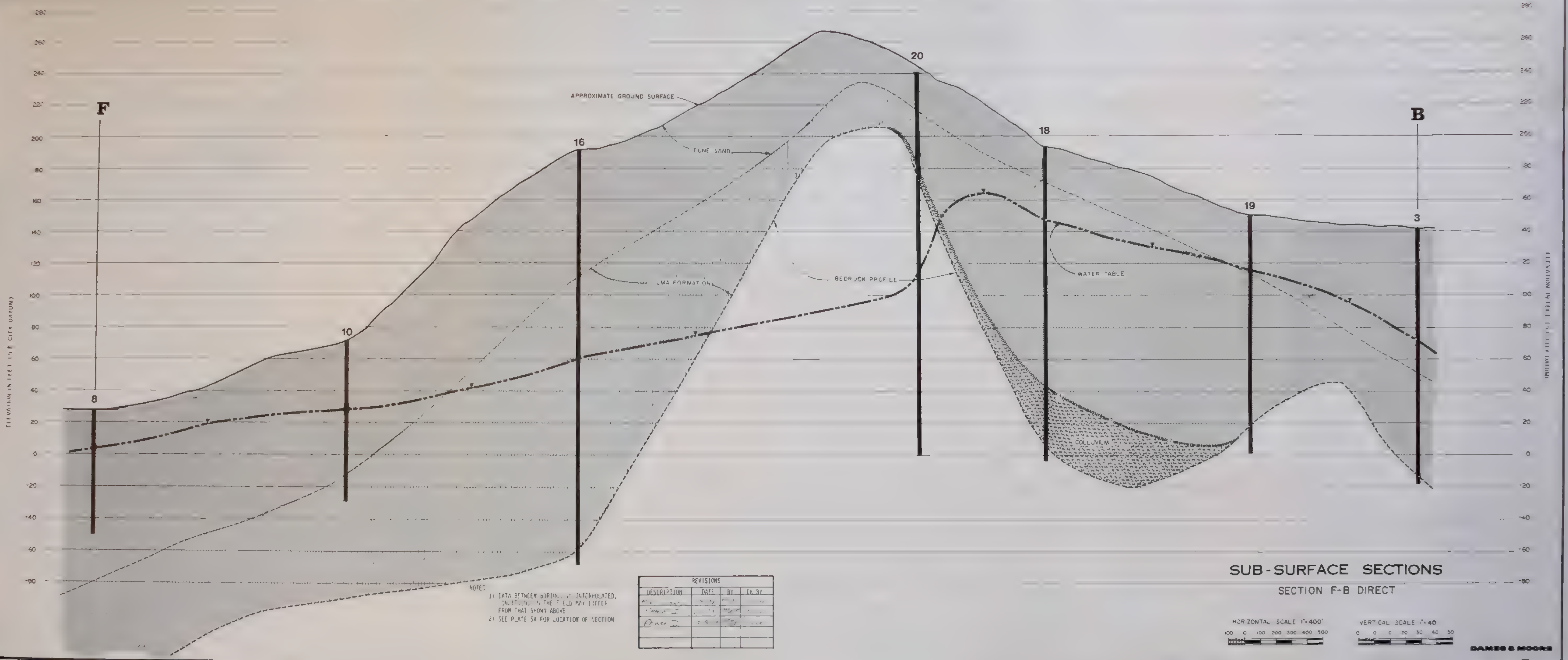


URFACE SECTIONS

CTION F-B DIRECT

**DAMES & MOORE**

PLATE 5B



NOTES

1) DATA BETWEEN BORINGS IS INTERPOLATED, CONDITIONS IN THE FIELD MAY DIFFER FROM THAT SHOWN ABOVE
2) SEE PLATE 5A FOR LOCATION OF SECTION

| REVISIONS | | | |
|---|---|---|---|
| DESCRIPTION | DATE | BY | CK BY |
| [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] |
| | | | |
| | | | |

## SUB-SURFACE SECTIONS

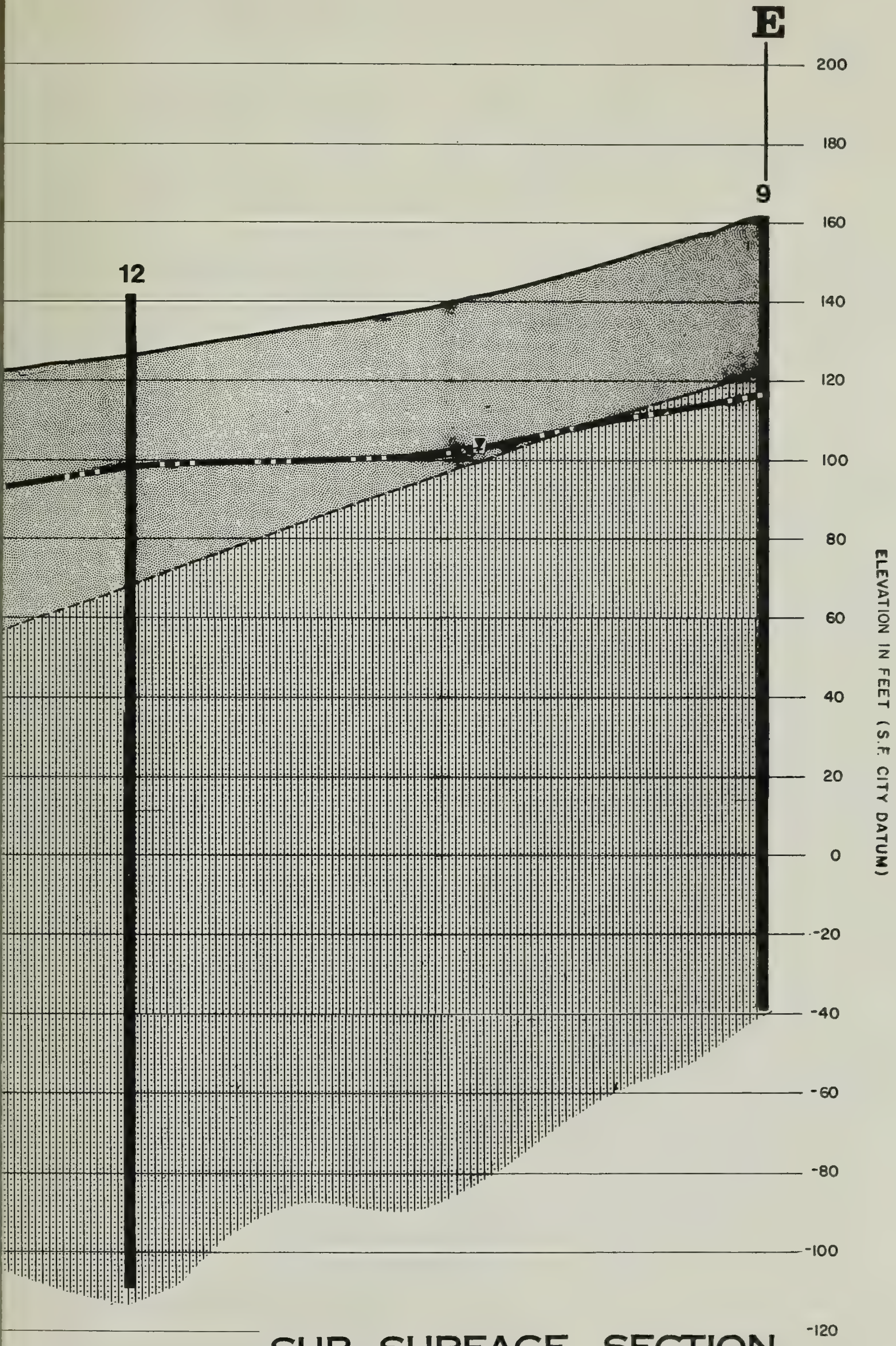
SECTION F-B DIRECT

HORIZONTAL SCALE 1"=400'
100 0 100 200 300 400 500

VERTICAL SCALE 1"=40
0 0 10 20 30 40 50

**DAMES & MOORE**

PLATE 5B



# SUB-SURFACE SECTION

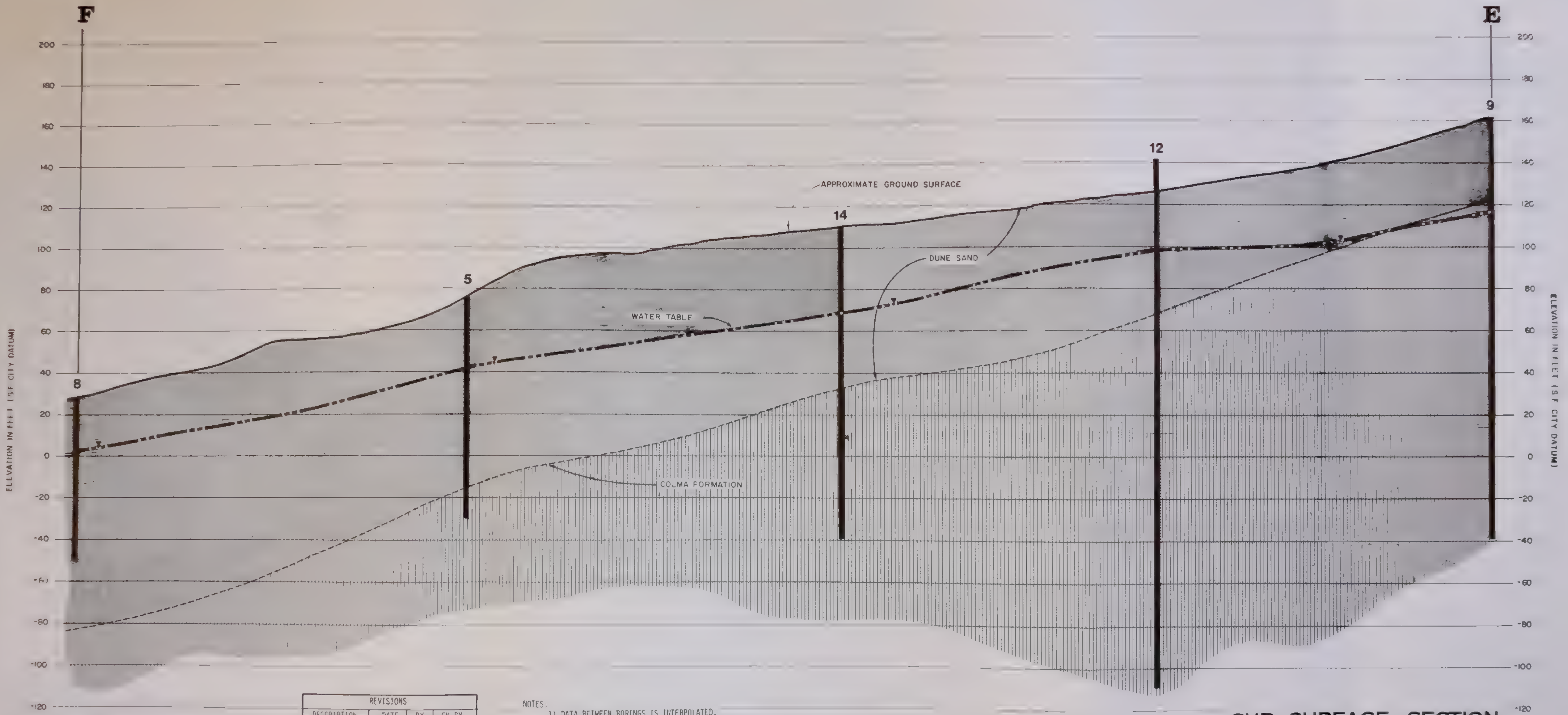
## SECTION F-E FULTON STREET

HORIZONTAL SCALE: 1"=400'
100 0 100 200 300 400 500

VERTICAL SCALE: 1"= 40'
10 0 10 20 30 40 50

**DAMES & MOORE**

PLATE 5C



| REVISIONS | | | |
|---|---|---|---|
| DESCRIPTION | DATE | BY | CK BY |
| Preliminary | [illegible] | [illegible] | [illegible] |
| Phase II | 07/73 | [illegible] | [illegible] |
| Phase III | 12/7 73 | [illegible] | [illegible] |
| | | | |
| | | | |

NOTES:

1) DATA BETWEEN BORINGS IS INTERPOLATED. CONDITIONS IN THE FIELD MAY DIFFER FROM THAT SHOWN ABOVE
2) SEE PLATE 5A FOR LOCATION OF SECTION.

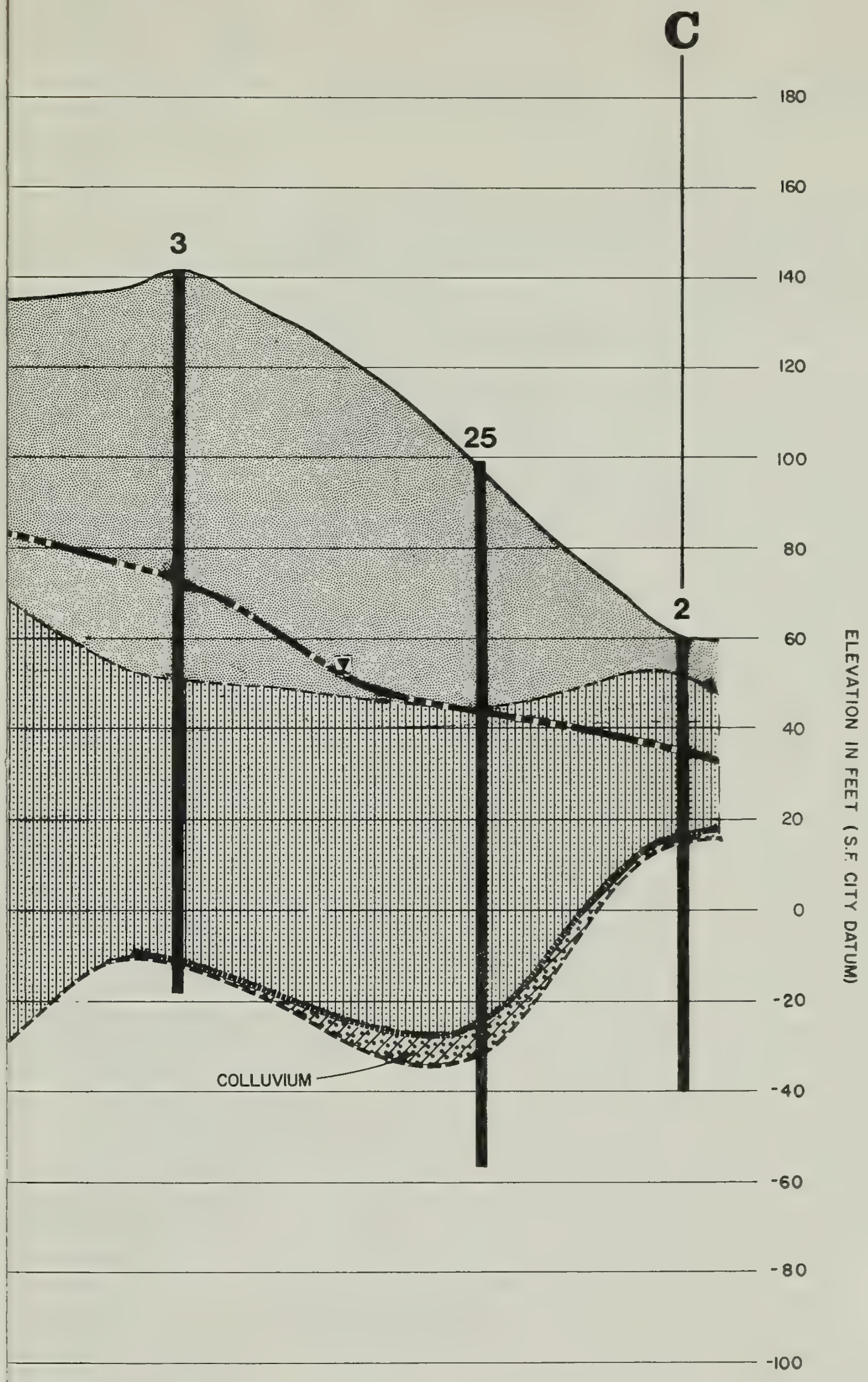
# SUB-SURFACE SECTION

## SECTION F-E FULTON STREET

HORIZONTAL SCALE 1"=400'
100 0 100 200 300 400 500

VERTICAL SCALE 1"=40'
10 0 10 20 30 40 50

DAMES & MOORE



# SUB-SURFACE SECTION

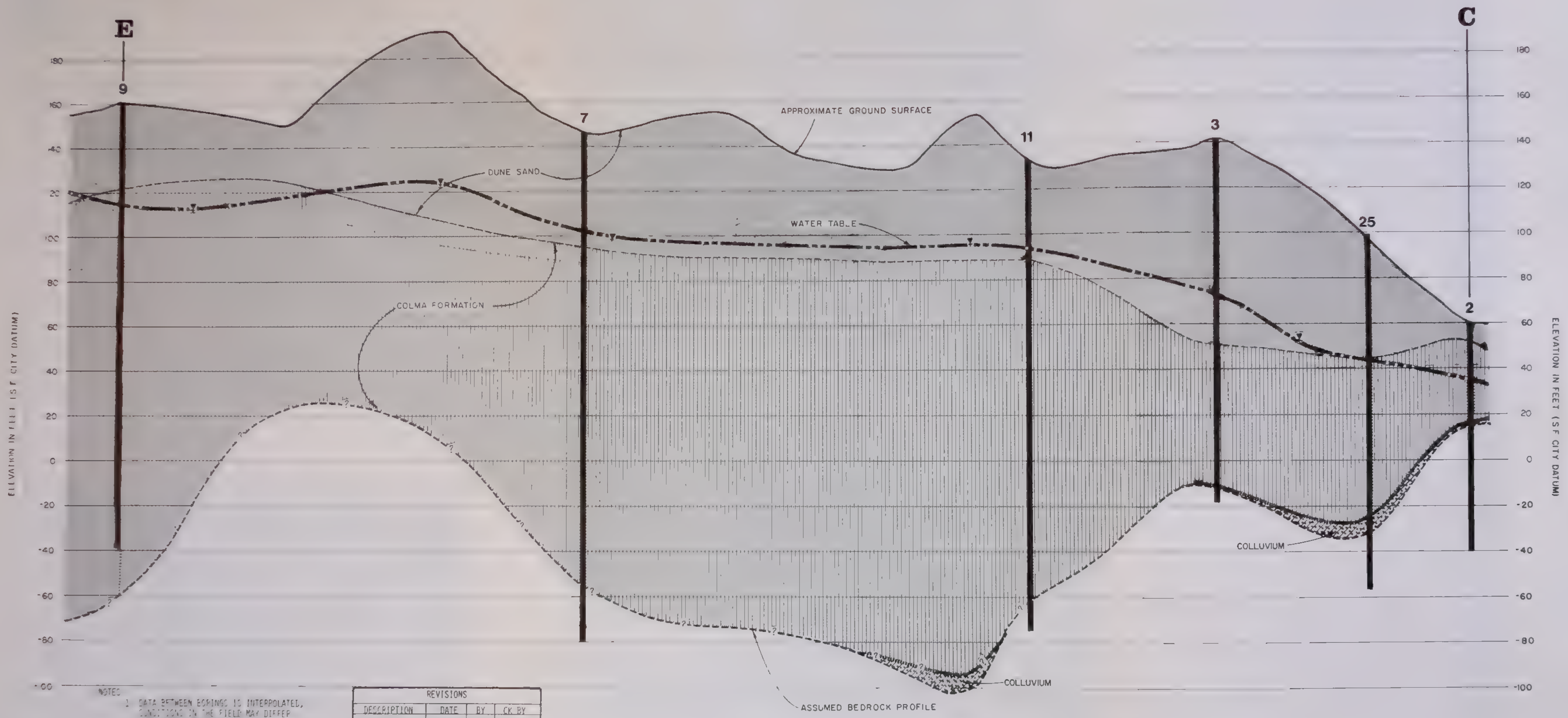
SECTION E-C 26TH AVENUE

HORIZONTAL SCALE: 1" = 400'
100 0 100 200 300 400 500

VERTICAL SCALE: 1" = 40'
10 0 10 20 30 40 50

**DAMES & MOORE**

PLATE 5D



NOTES

1. DATA BETWEEN BORINGS IS INTERPOLATED, CONDITIONS IN THE FIELD MAY DIFFER FROM THAT SHOWN ABOVE
2. SEE PLATE 5A FOR LOCATION OF SECTION

| REVISIONS | | | |
|---|---|---|---|
| DESCRIPTION | DATE | BY | CK BY |
| Preliminary | [illegible] | [illegible] | [illegible] |
| Phase II | [illegible] | [illegible] | [illegible] |
| Phase III | [illegible] | [illegible] | [illegible] |
| | | | |
| | | | |

# SUB-SURFACE SECTION

## SECTION E-C 26TH AVENUE

HORIZONTAL SCALE 1" = 400'
100 0 100 200 300 400 500

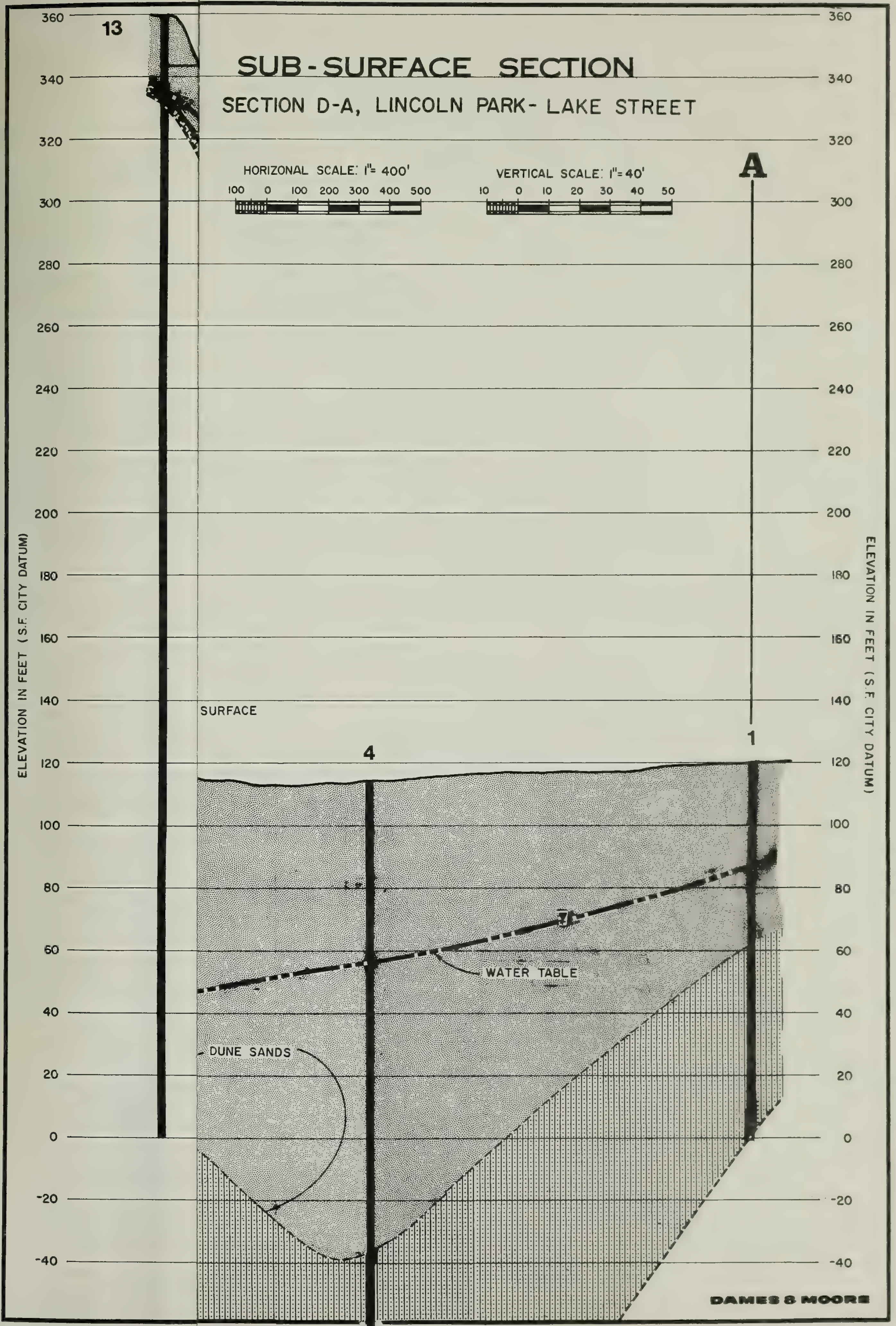
VERTICAL SCALE 1" = 40'
10 0 10 20 30 40 50

DAMES & MOORE

PLATE 5D

# SUB-SURFACE SECTION

## SECTION D-A, LINCOLN PARK - LAKE STREET

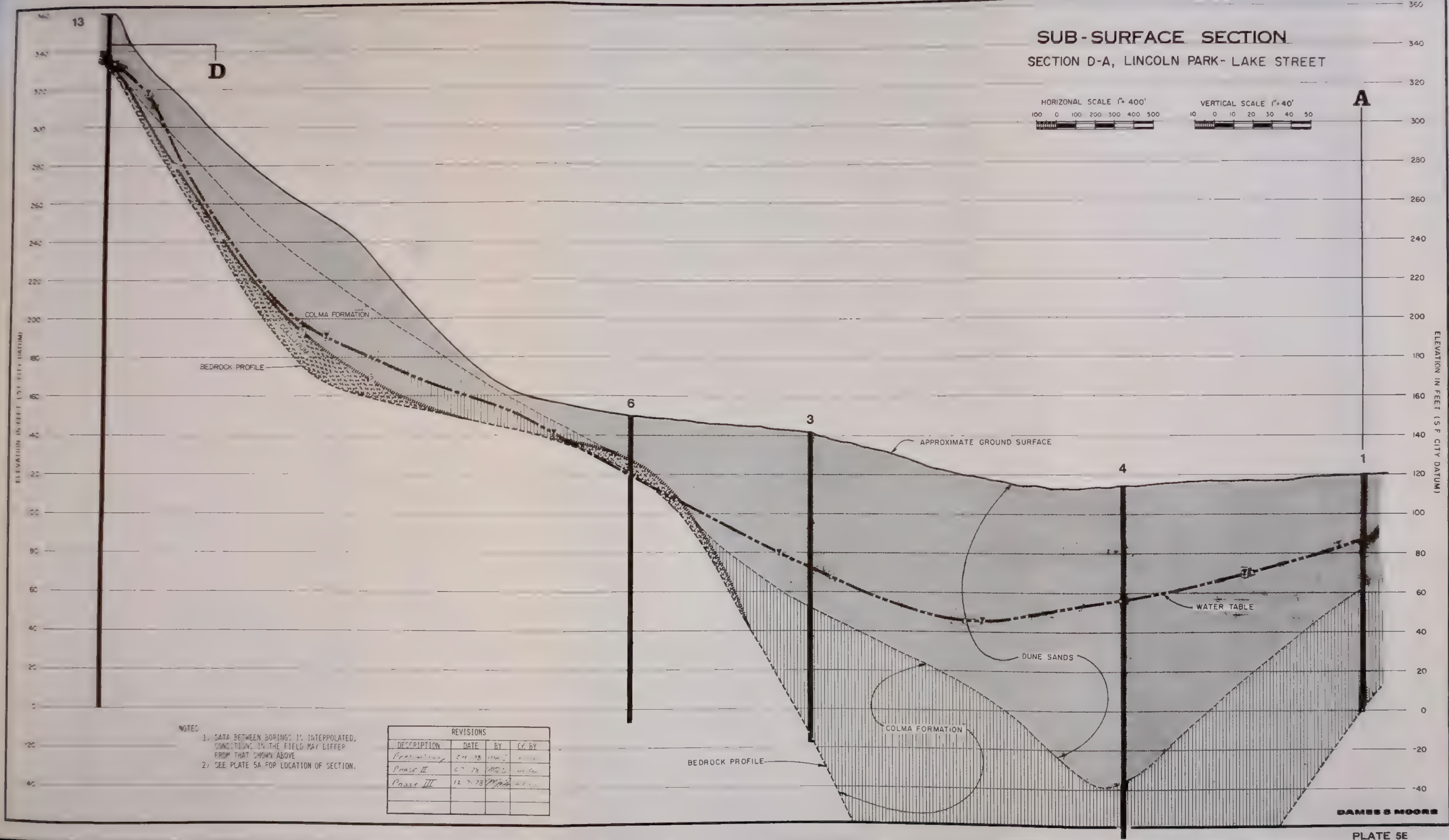


DAMES & MOORE

PLATE 5E

# SUB-SURFACE SECTION

## SECTION D-A, LINCOLN PARK- LAKE STREET

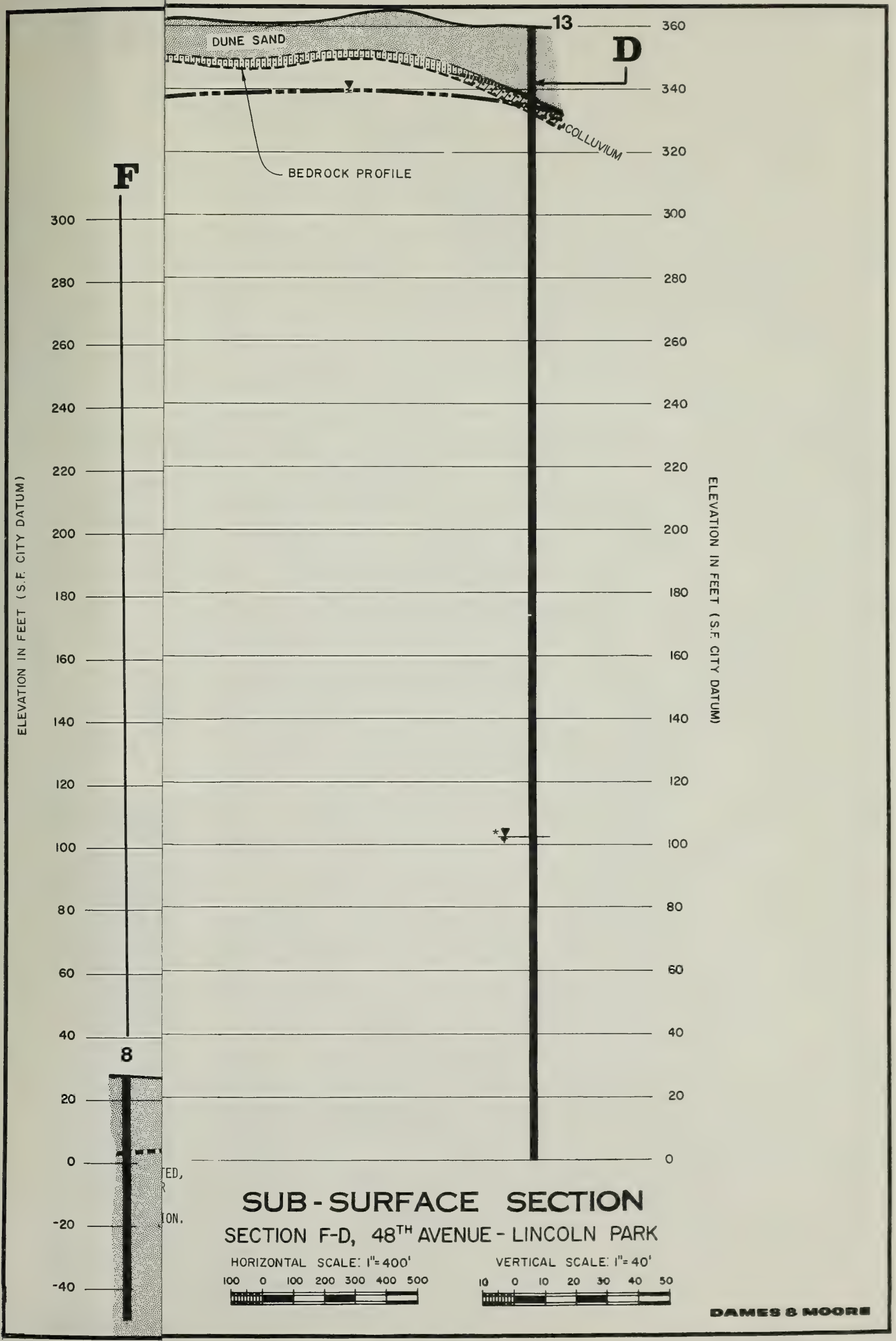


NOTES
1. DATA BETWEEN BORINGS IS INTERPOLATED, CONDITIONS IN THE FIELD MAY DIFFER FROM THAT SHOWN ABOVE
2) SEE PLATE 5A FOR LOCATION OF SECTION.

| REVISIONS | | | |
|---|---|---|---|
| DESCRIPTION | DATE | BY | CK BY |
| Preliminary | 5-4-78 | [illegible] | [illegible] |
| Phase II | 6-7-78 | [illegible] | [illegible] |
| Phase III | 12-7-78 | [illegible] | [illegible] |
| | | | |
| | | | |

DAMES & MOORE

PLATE 5E



## SUB-SURFACE SECTION

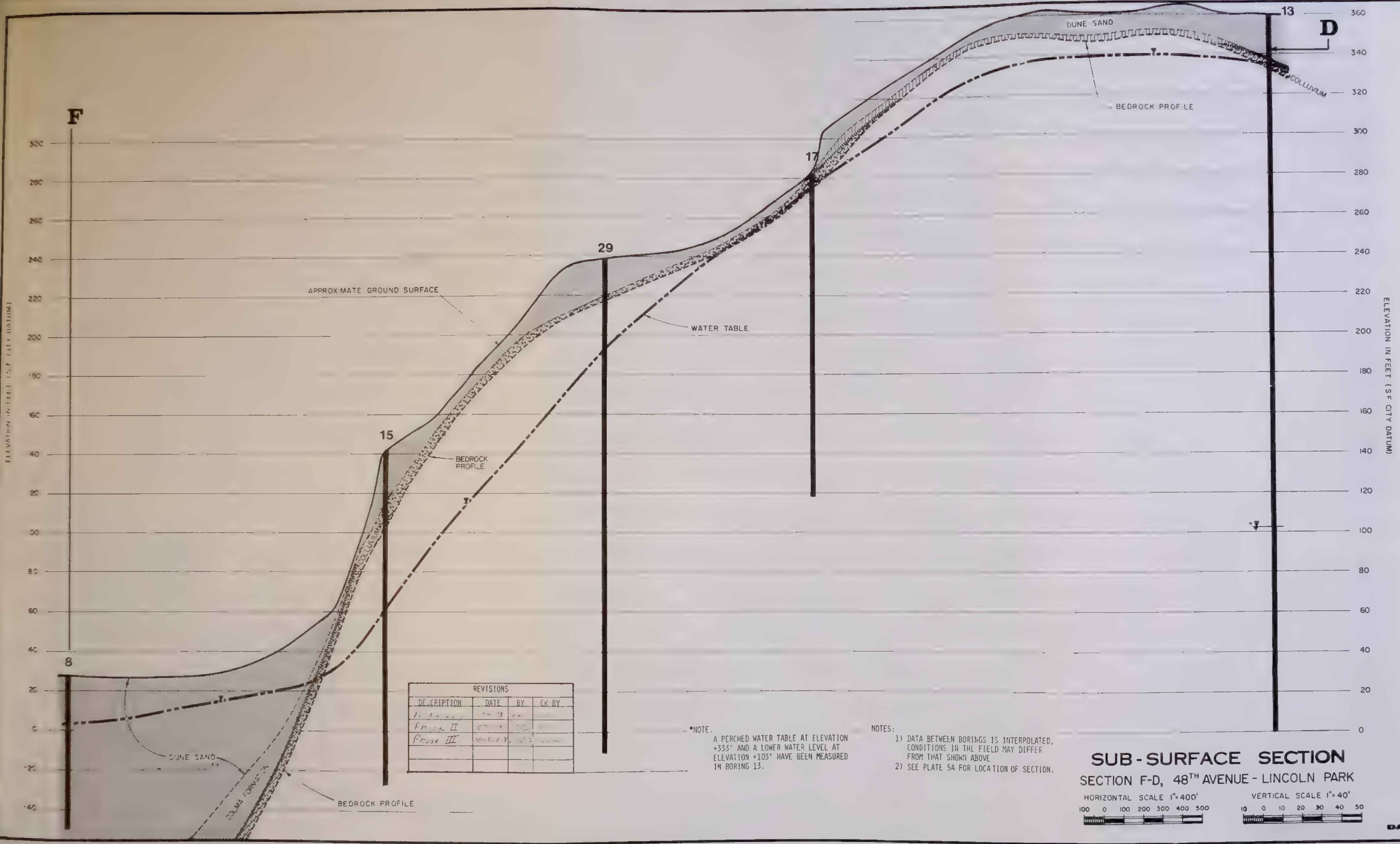
SECTION F-D, 48TH AVENUE - LINCOLN PARK

HORIZONTAL SCALE: 1"=400'

VERTICAL SCALE: 1"=40'

**DAMES & MOORE**

PLATE 5F



| REVISIONS | | | |
|---|---|---|---|
| DESCRIPTION | DATE | BY | CK BY |
| [illegible] | [illegible] | [illegible] | |
| Phase II | [illegible] | [illegible] | |
| Phase III | [illegible] | [illegible] | [illegible] |
| | | | |
| | | | |

*NOTE.
A PERCHED WATER TABLE AT ELEVATION +333' AND A LOWER WATER LEVEL AT ELEVATION +103' HAVE BEEN MEASURED IN BORING 13.

NOTES:
1) DATA BETWEEN BORINGS IS INTERPOLATED, CONDITIONS IN THE FIELD MAY DIFFER FROM THAT SHOWN ABOVE
2) SEE PLATE 5A FOR LOCATION OF SECTION.

# SUB-SURFACE SECTION

## SECTION F-D, 48TH AVENUE - LINCOLN PARK

HORIZONTAL SCALE 1"= 400'
100 0 100 200 300 400 500

VERTICAL SCALE 1"= 40'
10 0 10 20 30 40 50

DAMES & MOORE

PLATE 5F

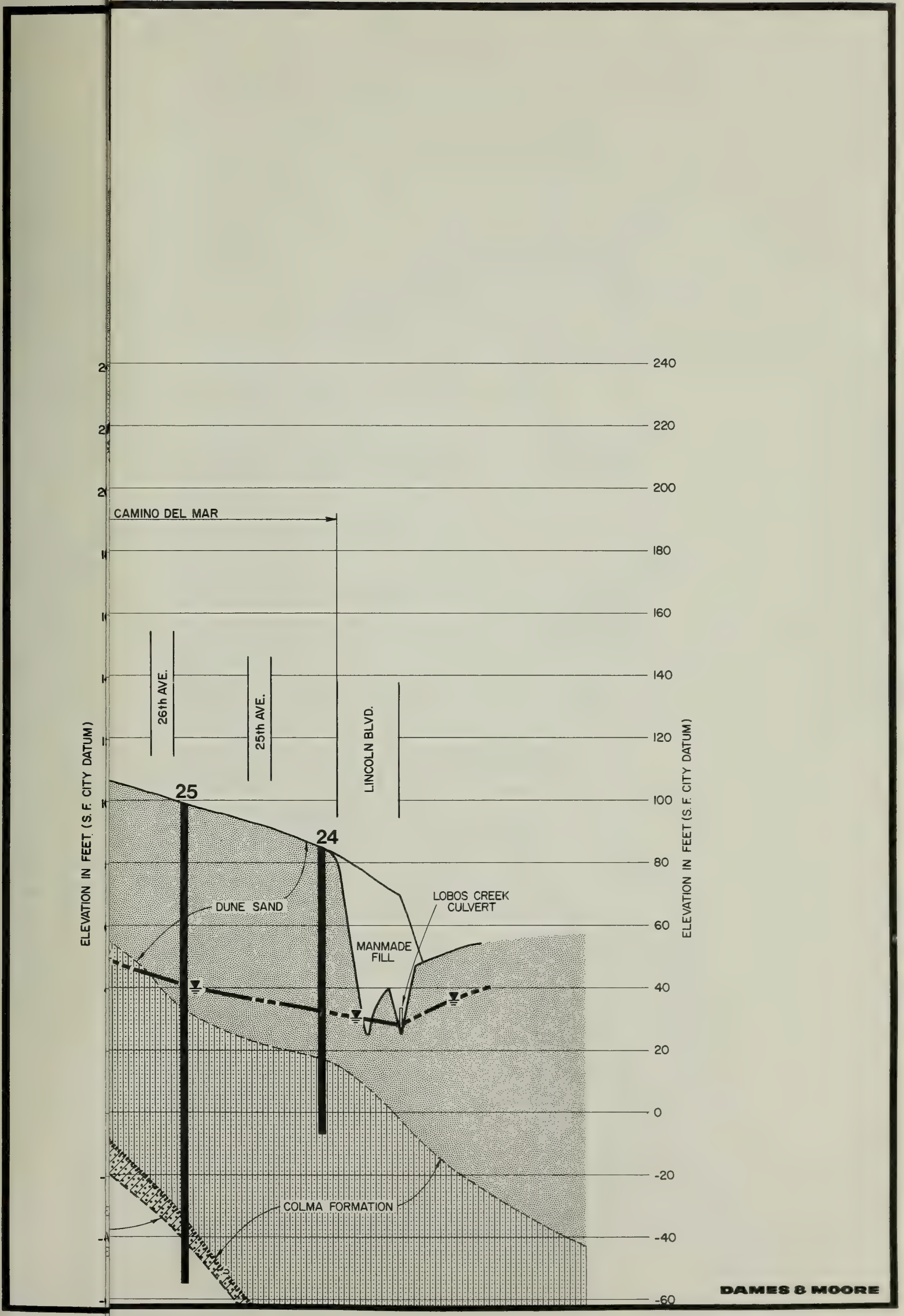
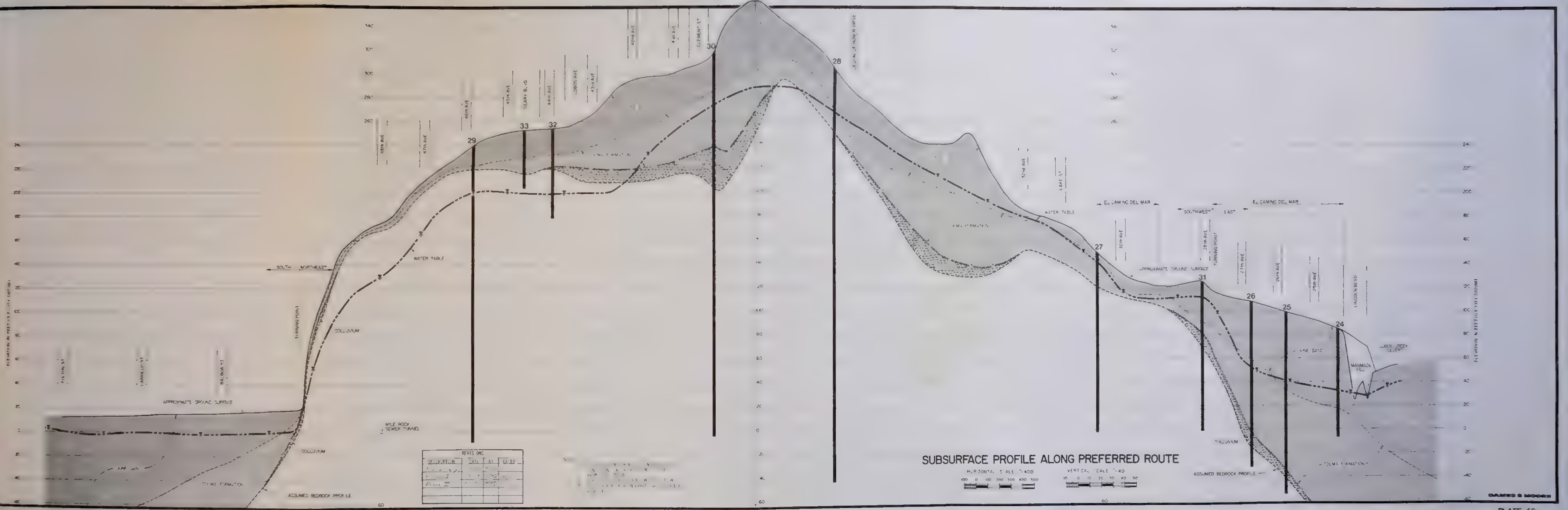

CAMINO DEL MAR
26th AVE.
25th AVE.
LINCOLN BLVD.
25
24
DUNE SAND
MANMADE FILL
LOBOS CREEK CULVERT
COLMA FORMATION
ELEVATION IN FEET (S.F. CITY DATUM)
ELEVATION IN FEET (S.F. CITY DATUM)
240
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
DAMES & MOORE

PLATE 5G



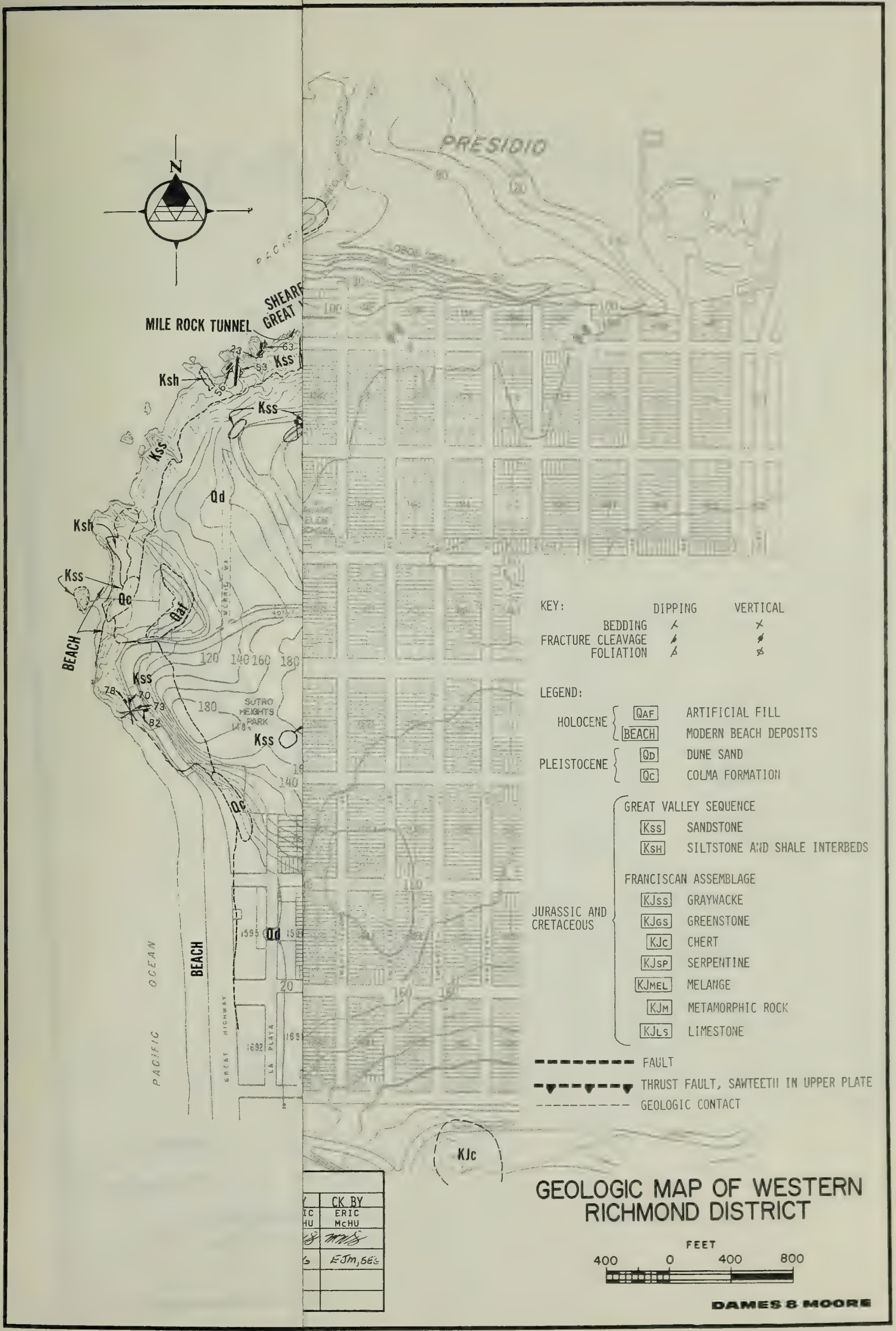
SUBSURFACE PROFILE ALONG PREFERRED ROUTE

HORIZONTAL SCALE 1":400'

VERTICAL SCALE 1":40'

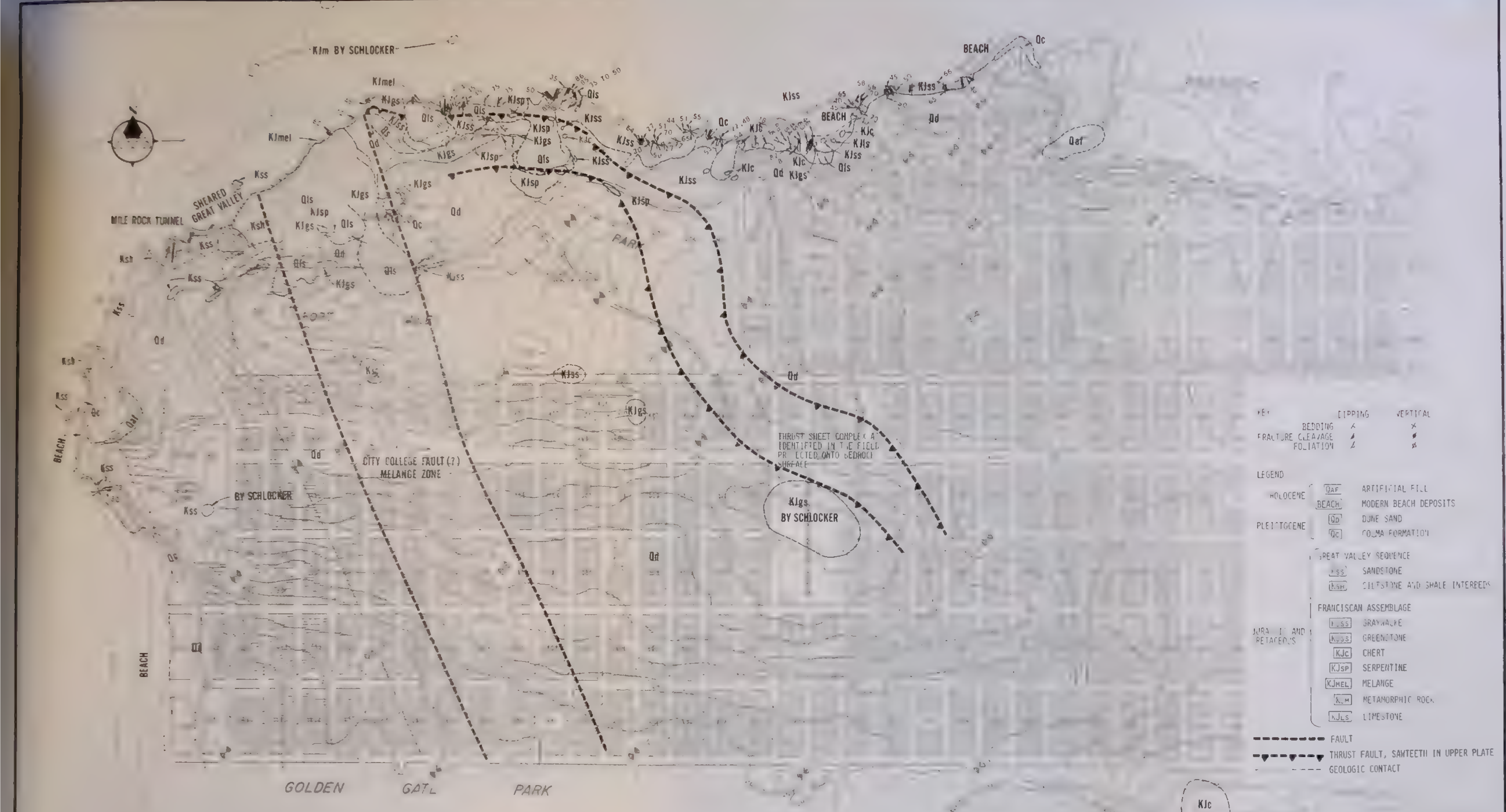
DAMES & MOORE

PLATE 5G



# GEOLOGIC MAP OF WESTERN RICHMOND DISTRICT

PLATE 6A



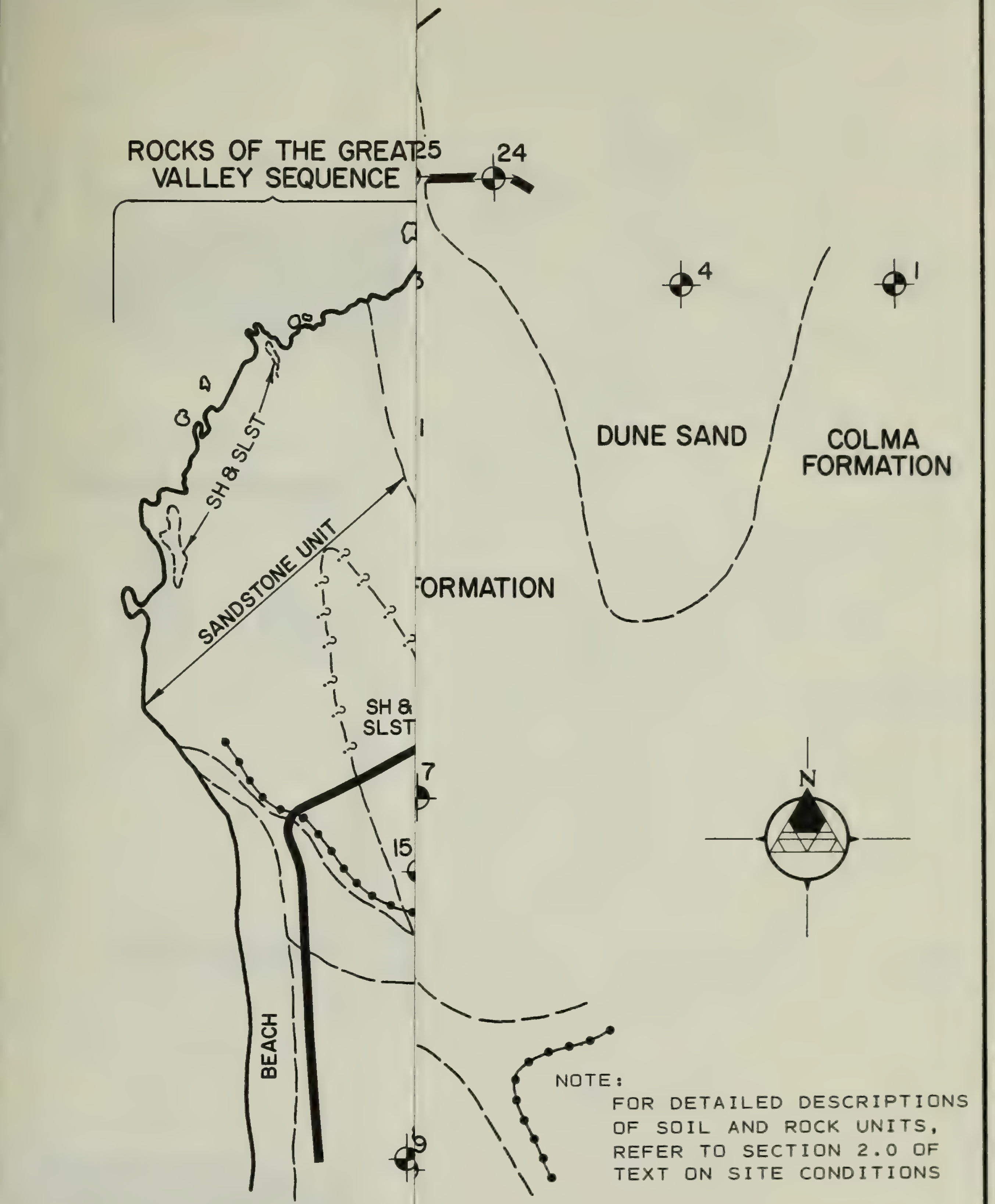
| REVISIONS | | | |
|---|---|---|---|
| DESCRIPTION | DATE | BY | CK BY |
| PRELIMINARY | 5/17/78 | ERIC McHU | ERIC McHU |
| Added | 7 26 8 | | |
| Revised | 2/15/79 | SEis | EJm se. |
| | | | |
| | | | |

# GEOLOGIC MAP OF WESTERN RICHMOND DISTRICT

FEET
400 0 400 800

**DAMES & MOORE**

PLATE 6A



NOTE:
FOR DETAILED DESCRIPTIONS OF SOIL AND ROCK UNITS, REFER TO SECTION 2.0 OF TEXT ON SITE CONDITIONS

## OGY AT TUNNEL INVERT LEVEL

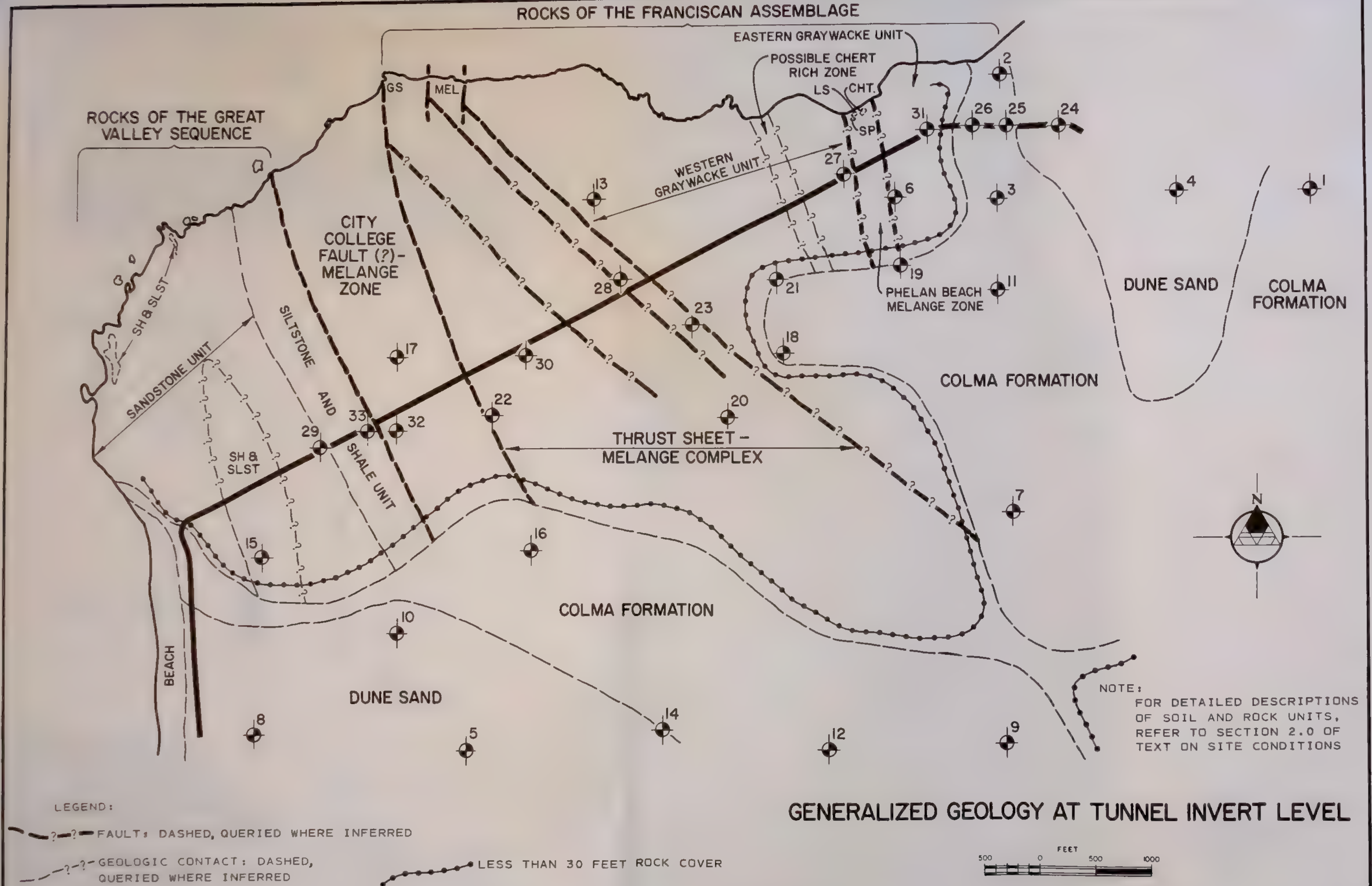
LEGEND:

—?—?— FAULT: DASHED, QUER

—?—?— GEOLOGIC CONTACT: QUERIED WHERE INFE

**DAMES & MOORE**

PLATE 6B



NOTE:
FOR DETAILED DESCRIPTIONS OF SOIL AND ROCK UNITS, REFER TO SECTION 2.0 OF TEXT ON SITE CONDITIONS

LEGEND:

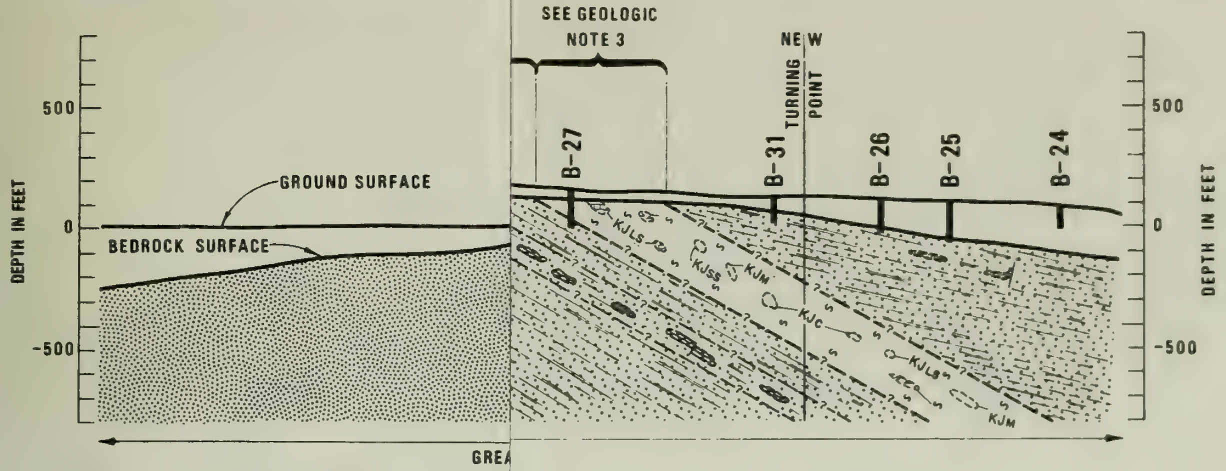
—?—?— FAULT: DASHED, QUERIED WHERE INFERRED

- -?-?- GEOLOGIC CONTACT: DASHED, QUERIED WHERE INFERRED

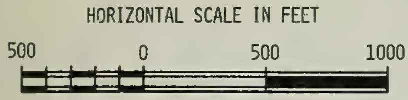
•—•—• LESS THAN 30 FEET ROCK COVER

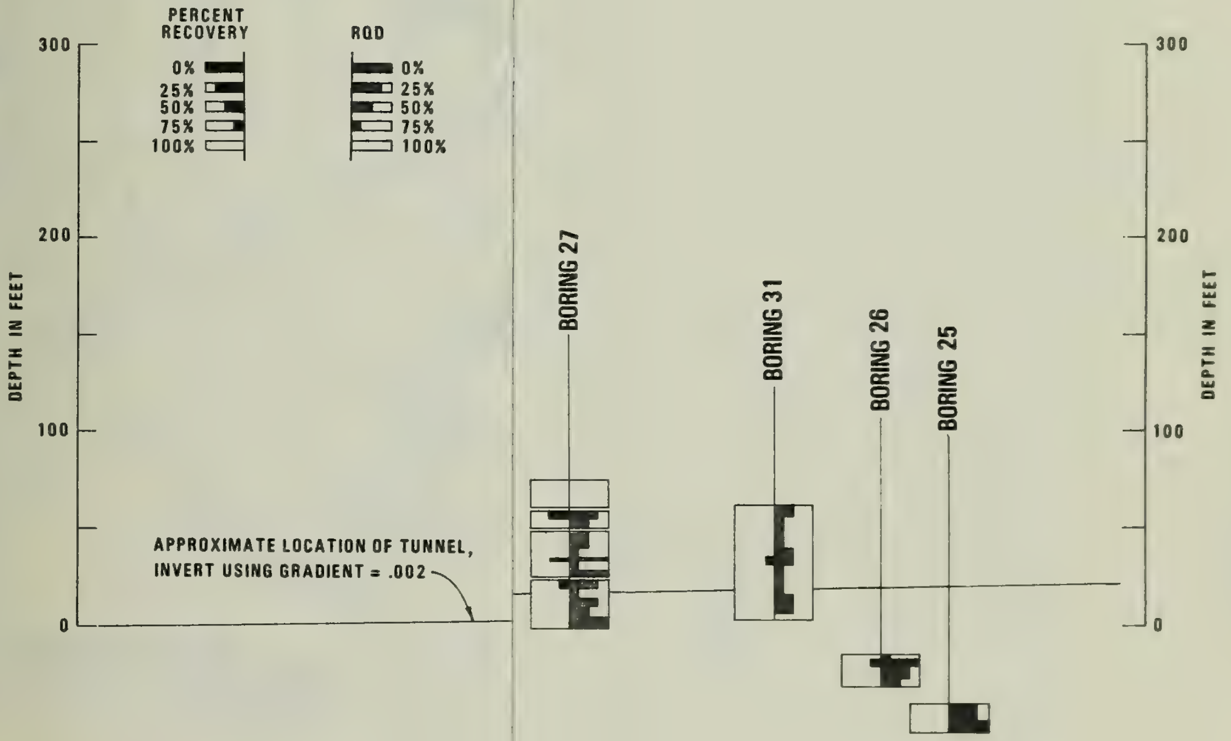
GENERALIZED GEOLOGY AT TUNNEL INVERT LEVEL

PLATE 6B



E





GEOLOGIC NOTES:

1. SILTSTONE-SHALE & CHERT INTERBEDS SHOWN HERE ARE PROJECTIONS ONTO THE CROSS SECTION OF FEATURES OBSERVED ALONG THE COAST. WHETHER THESE SAME FEATURES CONTINUE TO HERE IS NOT CERTAIN BUT SIMIL FEATURES MAY BE ENCOUNTERED ALONG THE TUNNEL ROUTE
2. THIS MELANGE ZONE APPEARS TO BE COMPOSED OF A SERIES OF SOUTHWEST DIPPING THRUST SHEETS AND TECT SLABS. THE ZONE IS CHARACTERIZED BY MASSIVE TECTON INCLUSIONS SEPARATED BY MINOR SHALE MATRIX AND SERPENTINE PODS. THREE THRUST SHEETS WERE IDENTIFI IN THE FIELD; HOWEVER, IT IS CONSIDERED LIKELY THA OTHERS EXIST.
3. THIS MELANGE ZONE WAS MAPPED ON THE BASIS OF A DIF IN THE CHARACTER OF THE GRAYWACKE ON EITHER SIDE, PRESENCE OF EXOTIC BLOCKS (LIMESTONE) IN THE ZONE THE PRESENCE OF A SHEAR ZONE IN BORING 27. THE EXA ATTITUDE AND WIDTH ARE NOT CERTAIN; HOWEVER, AN EA LOW ANGLE DIP APPEARS MOST LIKELY.
4. THIS MELANGE ZONE IS CHARACTERIZED BY SHEARED SHAL WITH UP TO 40% TECTONIC INCLUSIONS. THESE INCLUSIO COMMONLY COBBLE TO BOULDER SIZE BUT RANGE UP TO 20 IN SIZE.

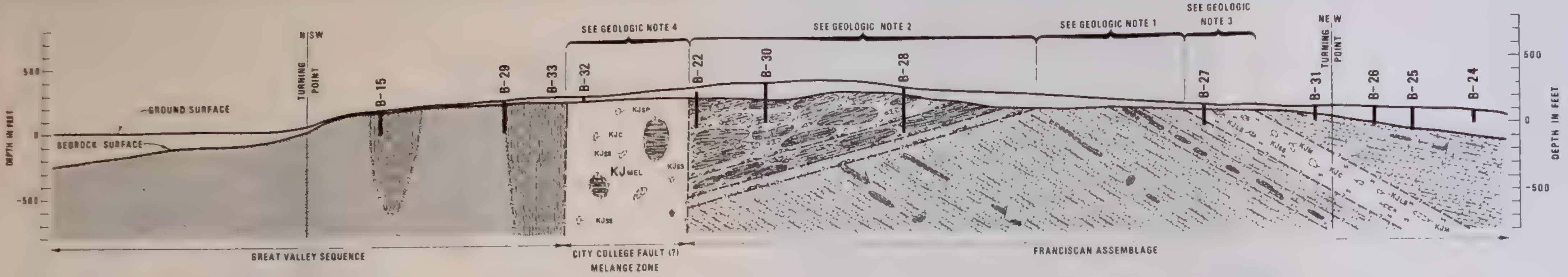
E ZONE

SHALE MATRIX
LUSIONS DERIVED
NCISCAN ASSEMBLAGE
T VALLEY SEQUENCE

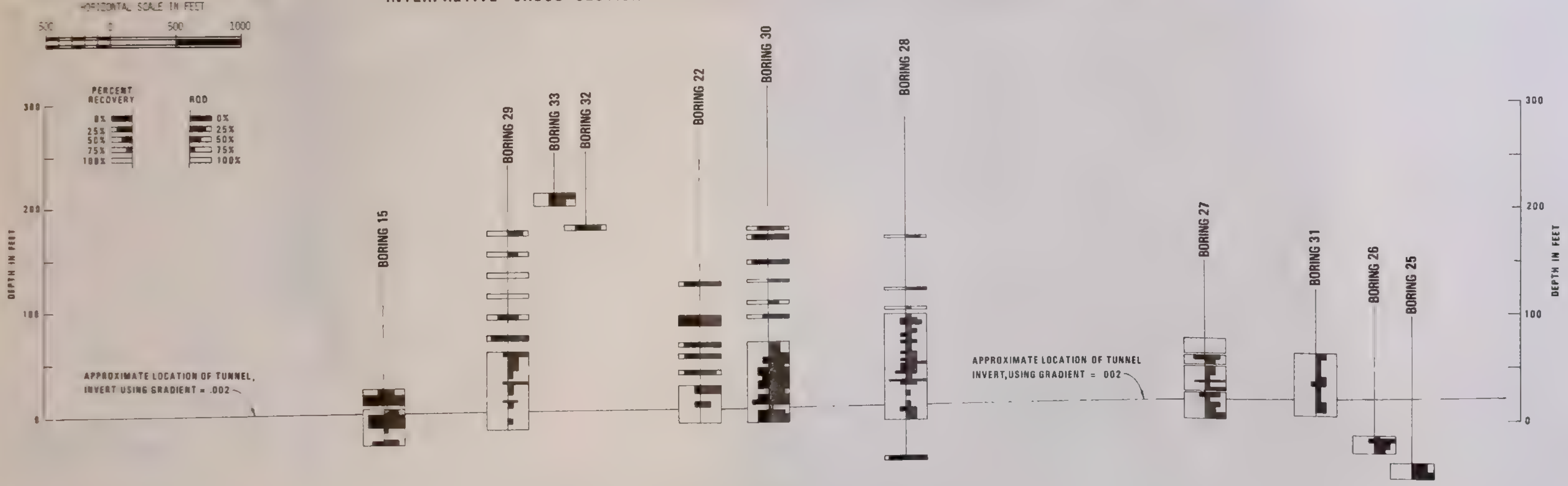
NOTE:
FOR LOCATION OF CROSS SECTION, REFER TO PLATE 6B.

# INTERPRETIVE CROSS SECTION OF BEDROCK GEOLOGY ALONG PREFERRED TUNNEL ROUTE

DAMES & MOORE



## INTERPRETIVE CROSS-SECTION OF BEDROCK GEOLOGY ALONG PREFERRED TUNNEL ROUTE



## PERCENT RECOVERY AND ROCK QUALITY DESIGNATION (RQD)
## VERTICAL EXAGGERATION • 8X

GEOLOGIC NOTES:

1. SILTSTONE-SHALE & CHERT INTERBEDS SHOWN HERE ARE PROJECTIONS ONTO THE CROSS SECTION OF FEATURES OBSERVED ALONG THE COAST. WHETHER THESE SAME FEATURES CONTINUE TO HERE IS NOT CERTAIN BUT SIMILAR FEATURES MAY BE ENCOUNTERED ALONG THE TUNNEL ROUTE.
2. THIS MELANGE ZONE APPEARS TO BE COMPOSED OF A SERIES OF SOUTHWEST DIPPING THRUST SHEETS AND TECTONIC SLABS. THE ZONE IS CHARACTERIZED BY MASSIVE TECTONIC INCLUSIONS SEPARATED BY MINOR SHALE MATRIX AND SERPENTINE PODS. THREE THRUST SHEETS WERE IDENTIFIED IN THE FIELD, HOWEVER, IT IS CONSIDERED LIKELY THAT OTHERS EXIST.
3. THIS MELANGE ZONE WAS MAPPED ON THE BASIS OF A DIFFERENCE IN THE CHARACTER OF THE GRAYWACKE ON EITHER SIDE, THE PRESENCE OF EXOTIC BLOCKS (LIMESTONE) IN THE ZONE AND THE PRESENCE OF A SHEAR ZONE IN BORING 27. THE EXACT ATTITUDE AND WIDTH ARE NOT CERTAIN, HOWEVER, AN EASTWARD, LOW ANGLE DIP APPEARS MOST LIKELY.
4. THIS MELANGE ZONE IS CHARACTERIZED BY SHEARED SHALE MATRIX WITH [illegible] TECTONIC INCLUSIONS. THESE INCLUSIONS ARE GENERALLY COBBLE TO BOULDER SIZE BUT RANGE UP TO 200 FEET IN SIZE.

LEGEND:

GREAT VALLEY SEQUENCE

UPPER CRETACEOUS
- Kss - SANDSTONE
- Ksh - INTERBEDDED SILTSTONE AND SHALE

FRANCISCAN ASSEMBLAGE

JURASSIC AND CRETACEOUS
- KJss - GRAYWACKE
- KJgs - GREENSTONE
- KJc - CHERT
- KJsp - SERPENTINE
- KJmel - MELANGE-GENERALLY INCLUSIONS OF THE ABOVE IN A SHEARED SHALE MATRIX
- KJsh - INTERBEDDED SHALE AND SILTSTONE
- KJls - LIMESTONE
- KJm - METAMORPHIC ROCK

CITY COLLEGE FAULT (?) - MELANGE ZONE

UPPER CRETACEOUS OR TERTIARY
- KJmel MELANGE-SHALE MATRIX WITH INCLUSIONS DERIVED FROM FRANCISCAN ASSEMBLAGE AND GREAT VALLEY SEQUENCE

GEOLOGIC CONTACT DASHED, QUERIED WHERE INFERRED

FAULT-DASHED QUERIED WHERE INFERRED

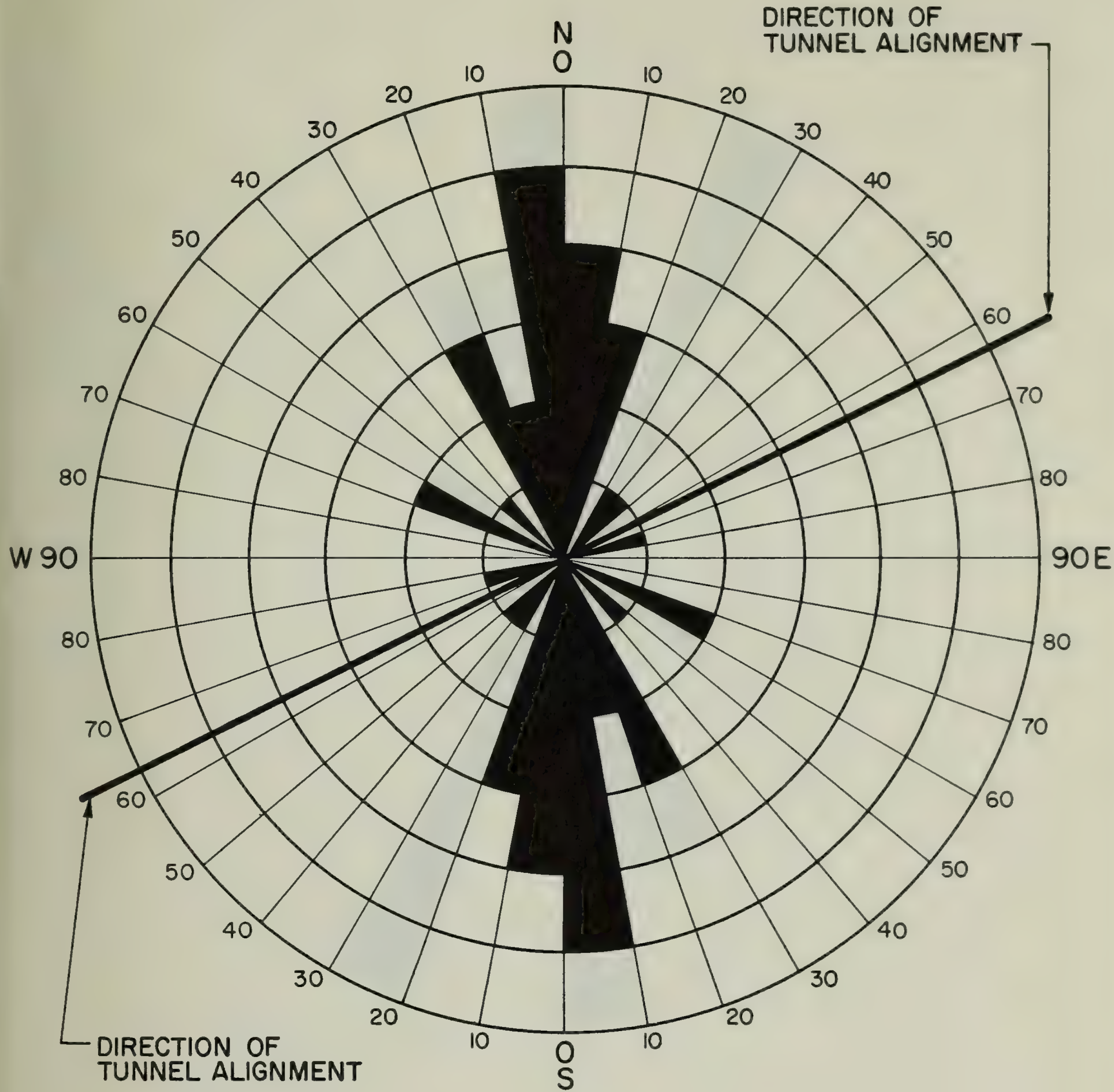
B-28 LOCATION OF BOREHOLE OR PROJECTION OF BOREHOLE ON CROSS SECTION

BEDDING ORIENTATION INDICATOR

NOTE:
FOR LOCATION OF CROSS SECTION, REFER TO PLATE 6B.

## INTERPRETIVE CROSS SECTION
## OF BEDROCK GEOLOGY
## ALONG PREFERRED TUNNEL ROUTE

**DAMES & MOORE**



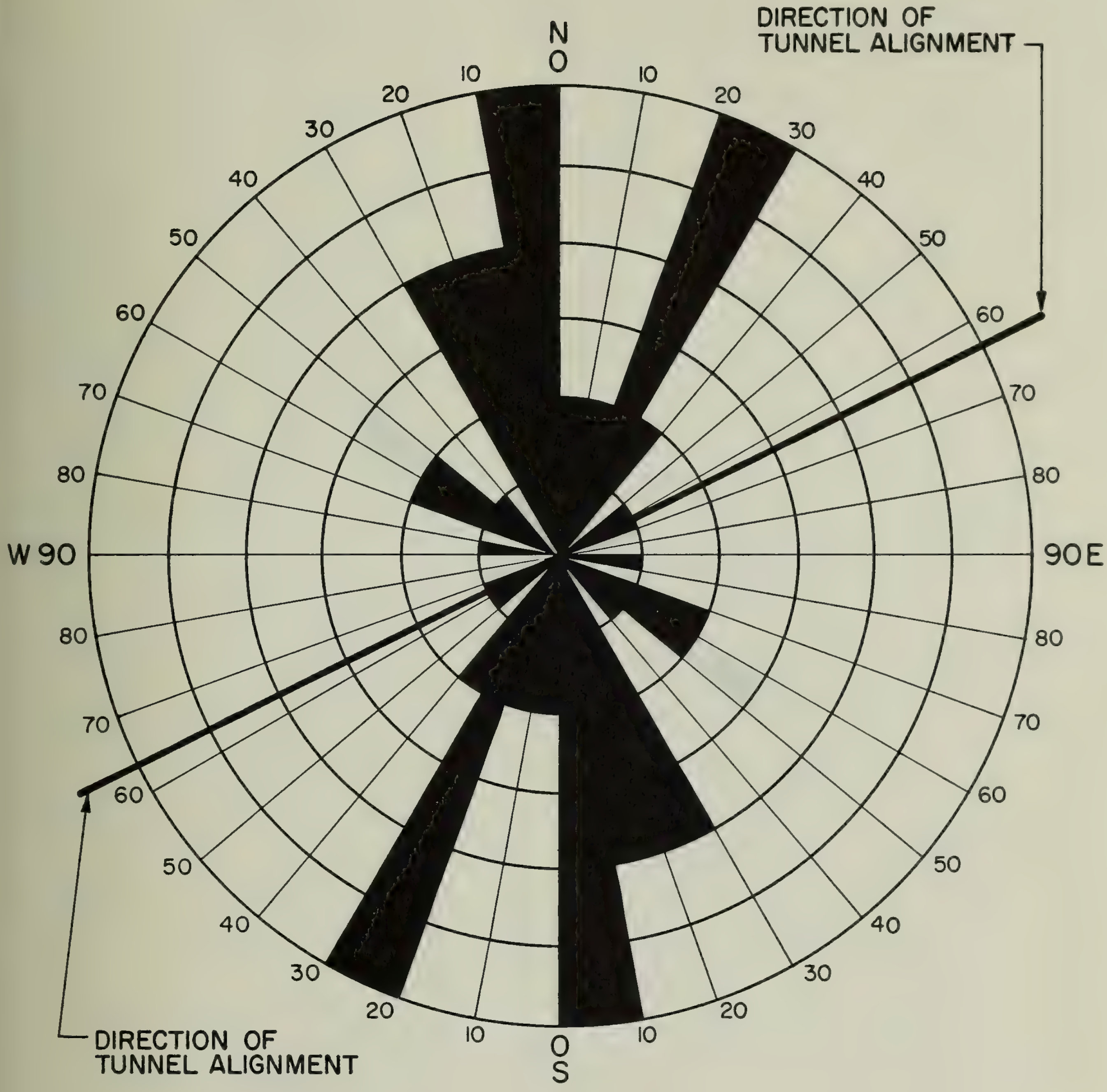
NOTES:

1) 23 DATA POINTS
2) EACH RING REPRESENTS ONE OBSERVATION

## ROSE DIAGRAM OF BEDDING

IN GRAYWACKE WEST OF PHELAN BEACH

DAMES & MOORE



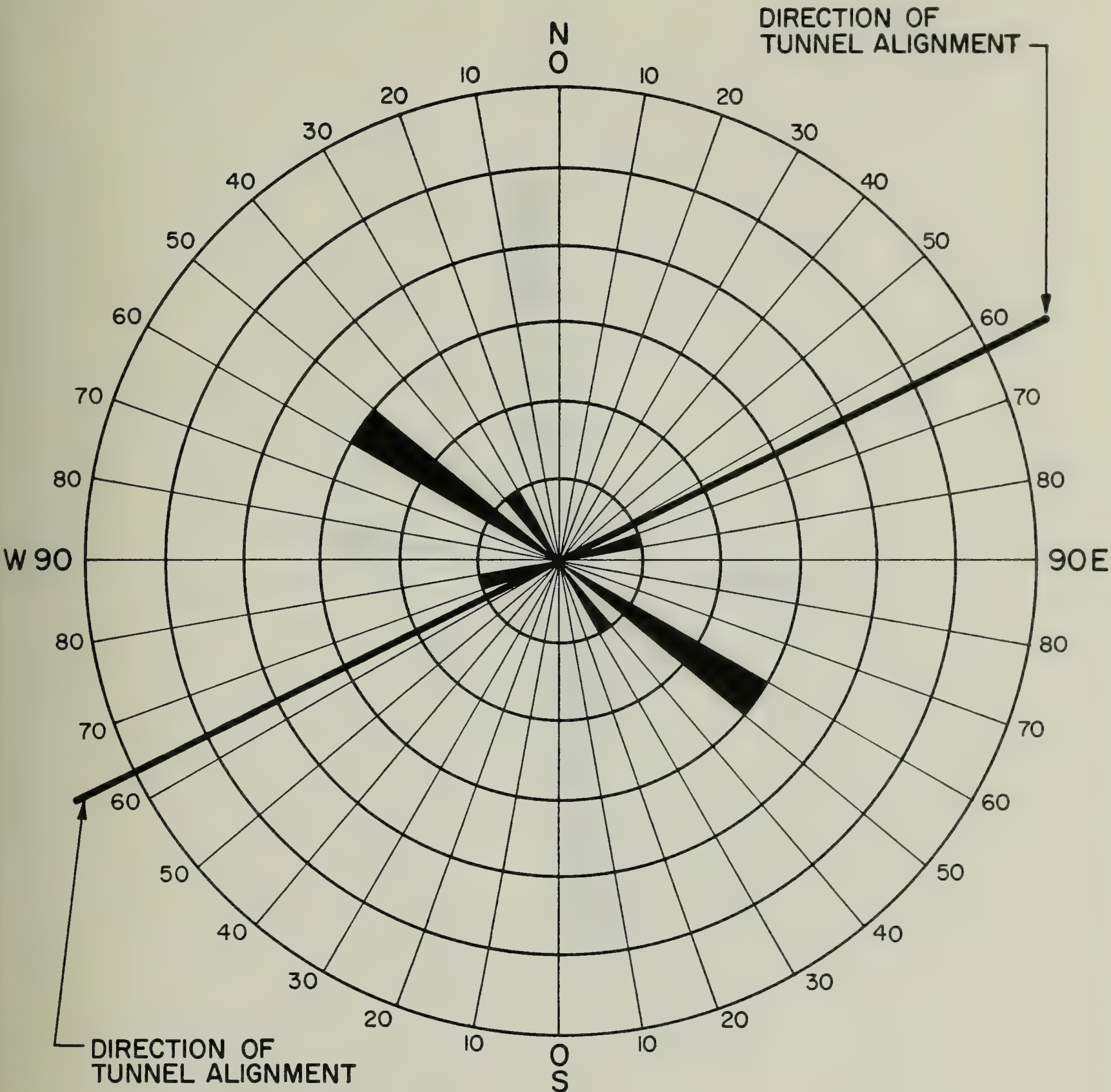
NOTES:

1) 34 DATA POINTS
2) EACH RING REPRESENTS ONE OBSERVATION

# ROSE DIAGRAM OF FAULTS, FRACTURES AND SHEAR ZONES

## IN GRAYWACKE WEST OF PHELAN BEACH

**DAMES & MOORE**



NOTES:

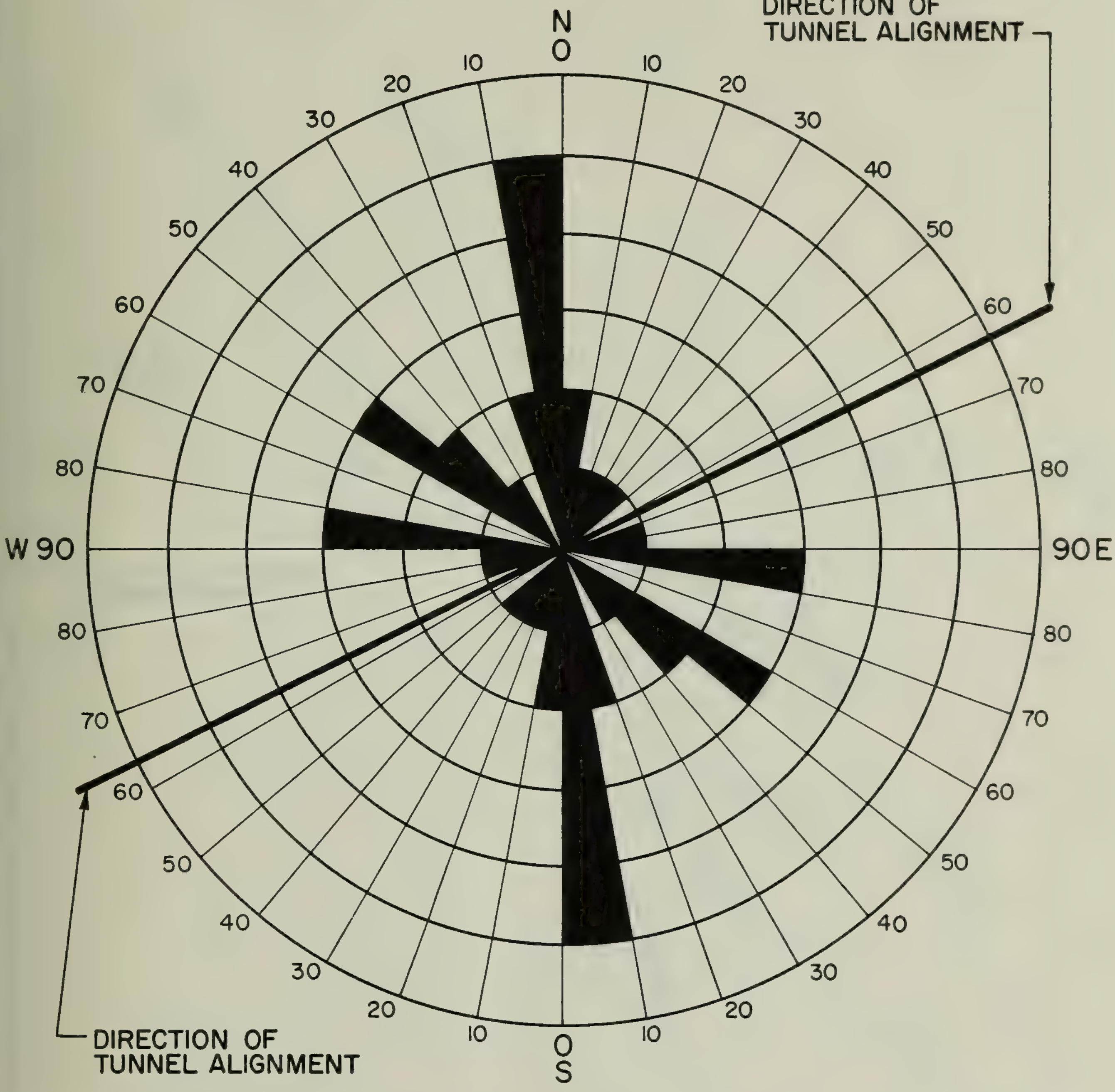
1) 5 DATA POINTS

2) EACH RING REPRESENTS ONE OBSERVATION

# ROSE DIAGRAM OF BEDDING

IN GRAYWACKE EAST OF PHELAN BEACH

**DAMES & MOORE**



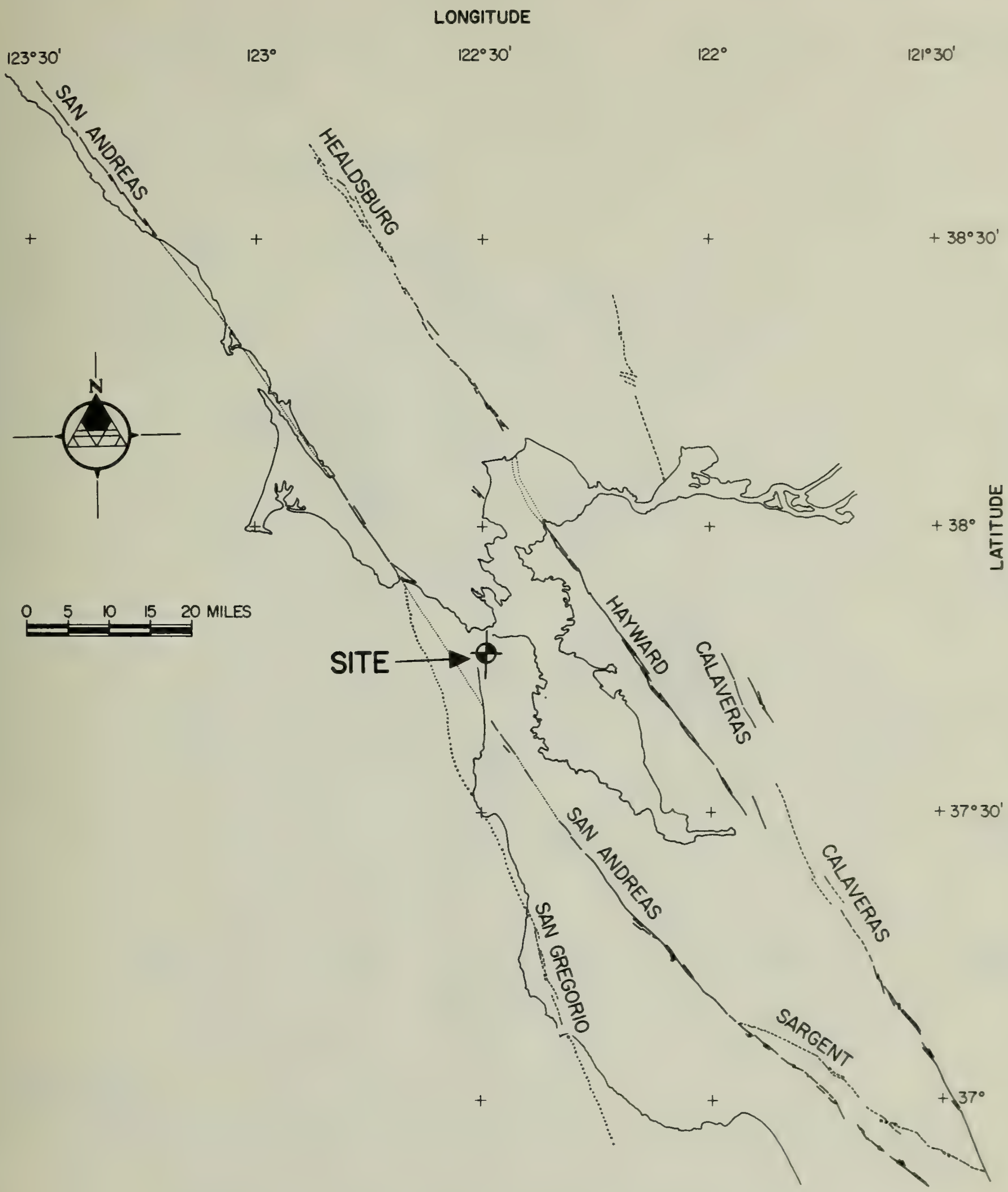
NOTES:

1) 24 DATA POINTS
2) EACH RING REPRESENTS ONE OBSERVATION

# ROSE DIAGRAM OF FAULTS, FRACTURES AND SHEAR ZONES

IN GRAYWACKE EAST OF PHELAN BEACH

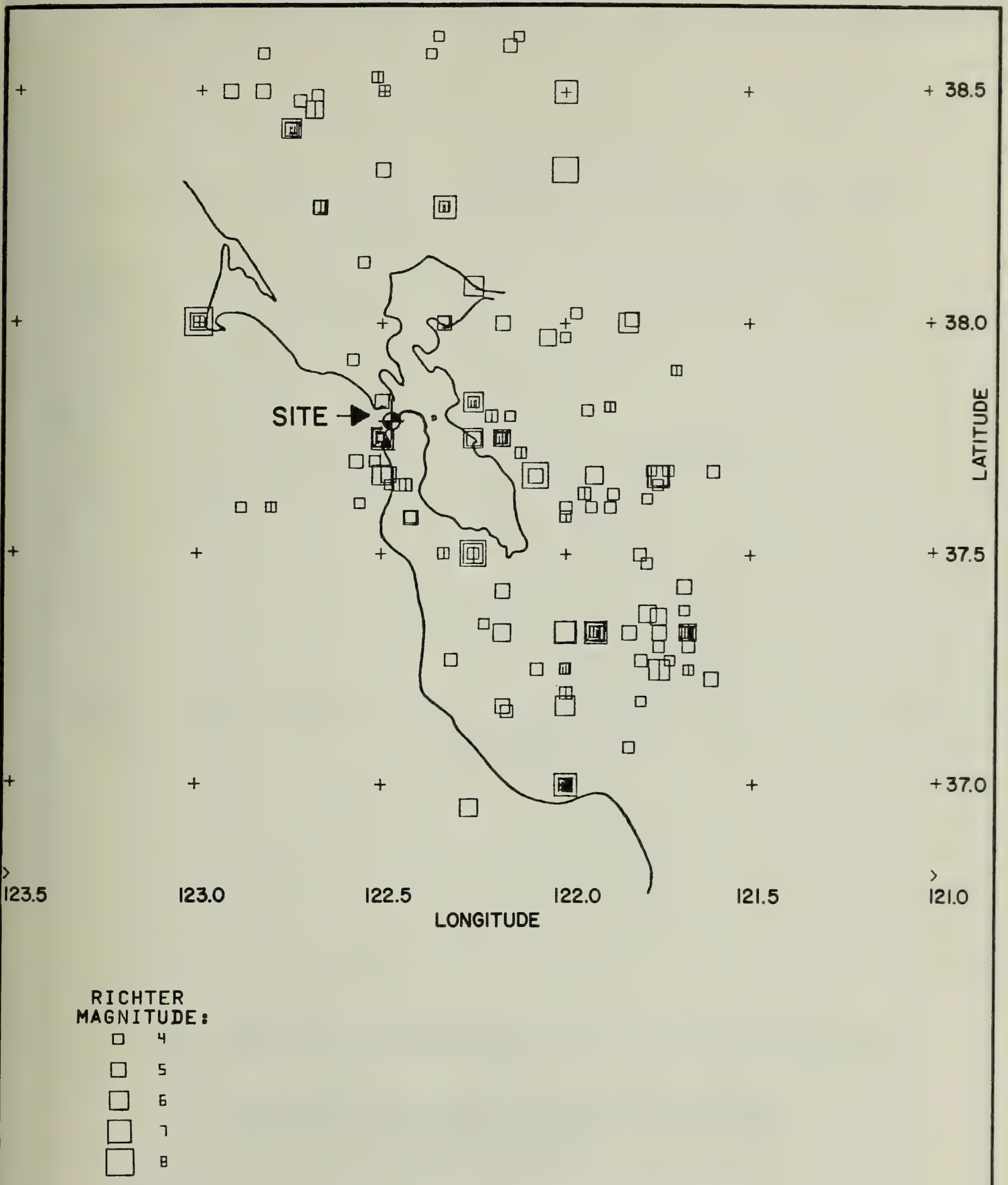
DAMES & MOORE



# MAJOR ACTIVE OR POTENTIALLY ACTIVE FAULTS IN THE SAN FRANCISCO BAY AREA

SOURCE:
JENNINGS, C.W. ET.AL.; 1975, FAULT MAP OF CALIFORNIA WITH LOCATION OF VOLCANOES, THERMAL SPRINGS AND THERMAL WELLS; CALIFORNIA GEOLOGIC DATA MAP SERIES, MAP NO. 1, CALIFORNIA DIVISION OF MINES AND GEOLOGY

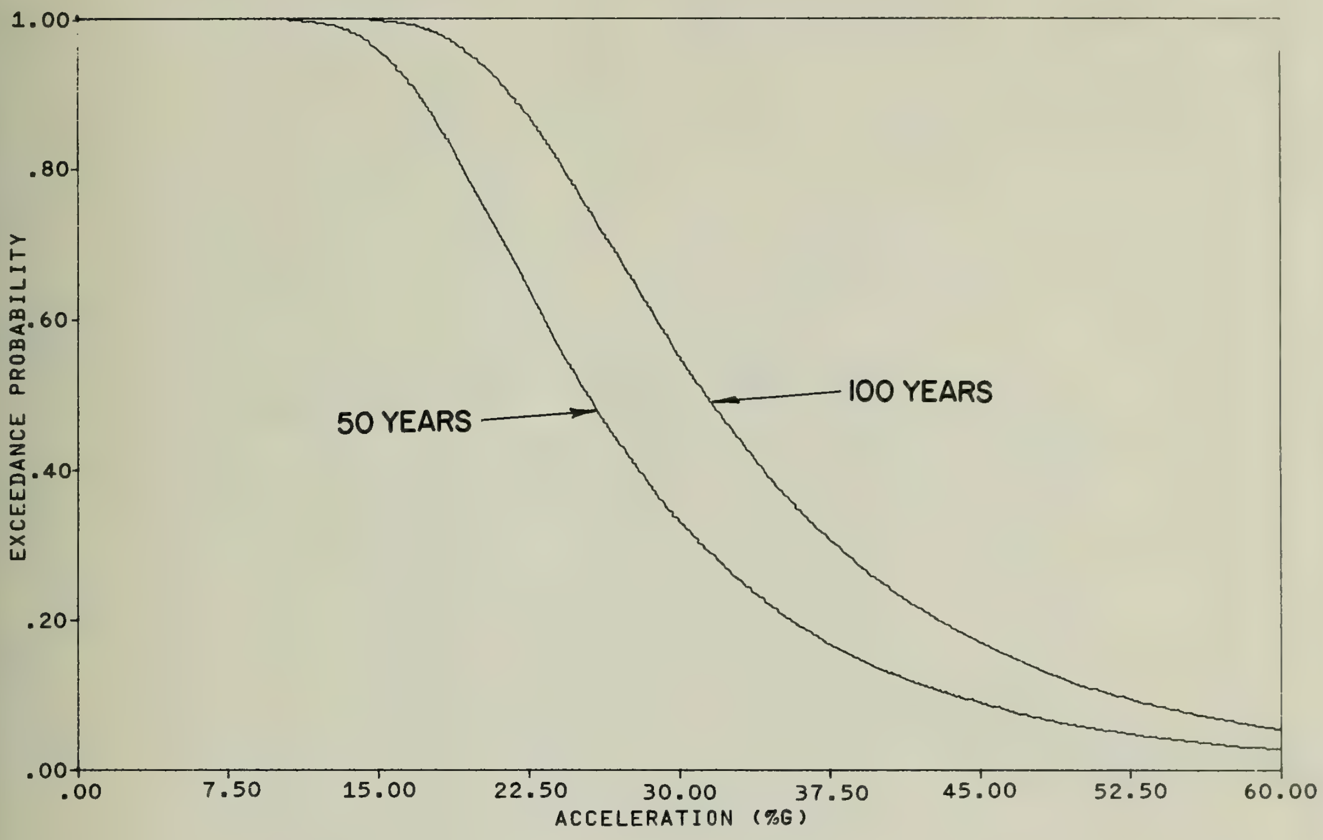
DAMES & MOORE



REPORTED EPICENTRAL LOCATIONS
(1808-1976)

NOTE:

PRE-1930 EPICENTER LOCATIONS WERE OFTEN REPORTED
AT POPULATION CENTERS, NOT AT THE ACTUAL (INSTUMENTAL)
EPICENTER LOCATION, SEE TEXT FOR DISCUSSION



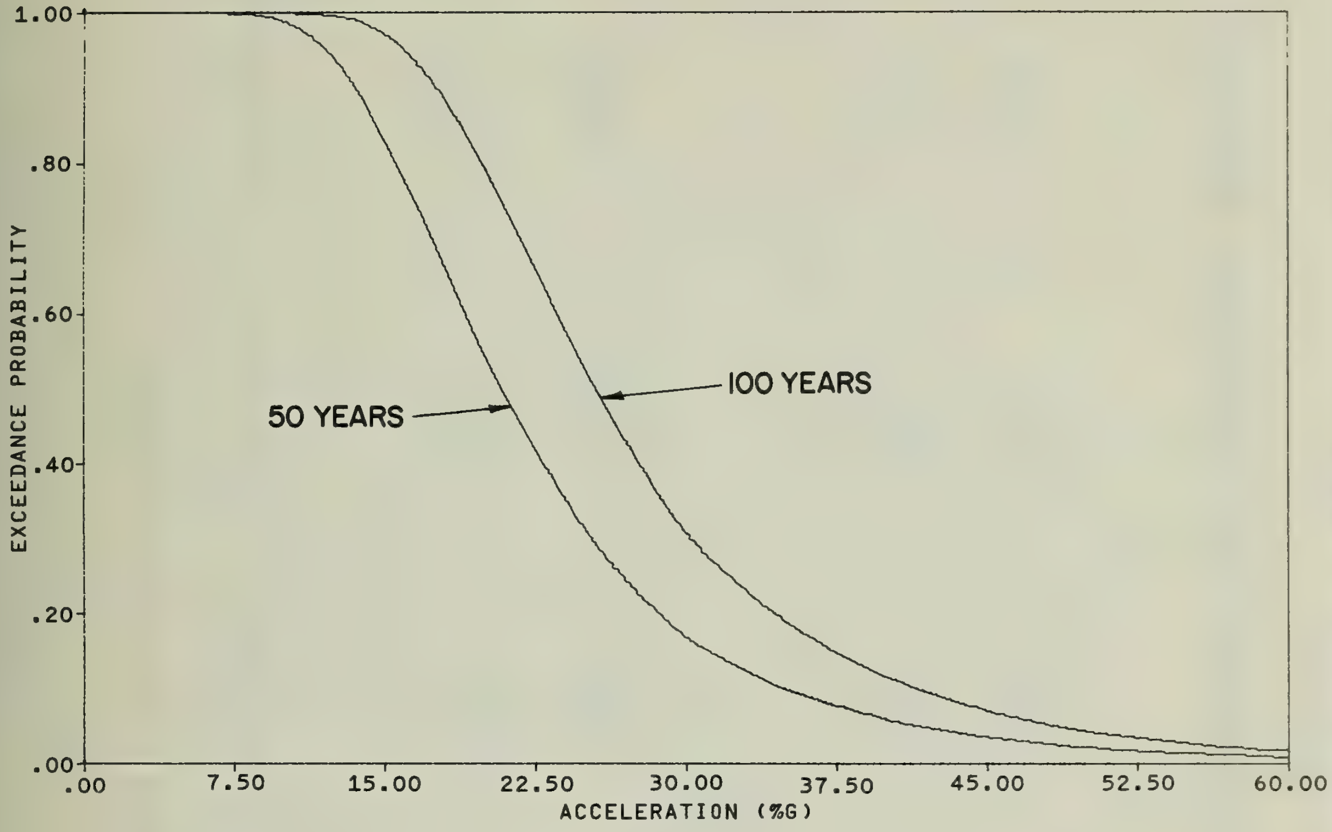
# EXCEEDANCE PROBABILITIES: SOIL EQUATION

PROBABILITIES THAT MAXIMUM ACCELERATION LEVELS WILL BE EXCEEDED DURING THE DESIGN LIFE OF THE STRUCTURE COMPUTED BY THE SOIL SITE ATTENUATION EQUATION.

NOTE:

SEE APPENDIX D FOR ATTENUATION EQUATION DERIVED FROM SOIL SITES

**DAMES & MOORE**



# EXCEEDANCE PROBABILITIES: ROCK EQUATION

PROBABILITIES THAT MAXIMUM ACCELERATION LEVELS WILL BE EXCEEDED DURING THE DESIGN LIFE OF THE STRUCTURE COMPUTED BY THE ROCK SITE ATTENUATION EQUATION.

NOTE:

SEE APPENDIX D FOR ATTENUATION EQUATION DERIVED FROM ROCK SITES

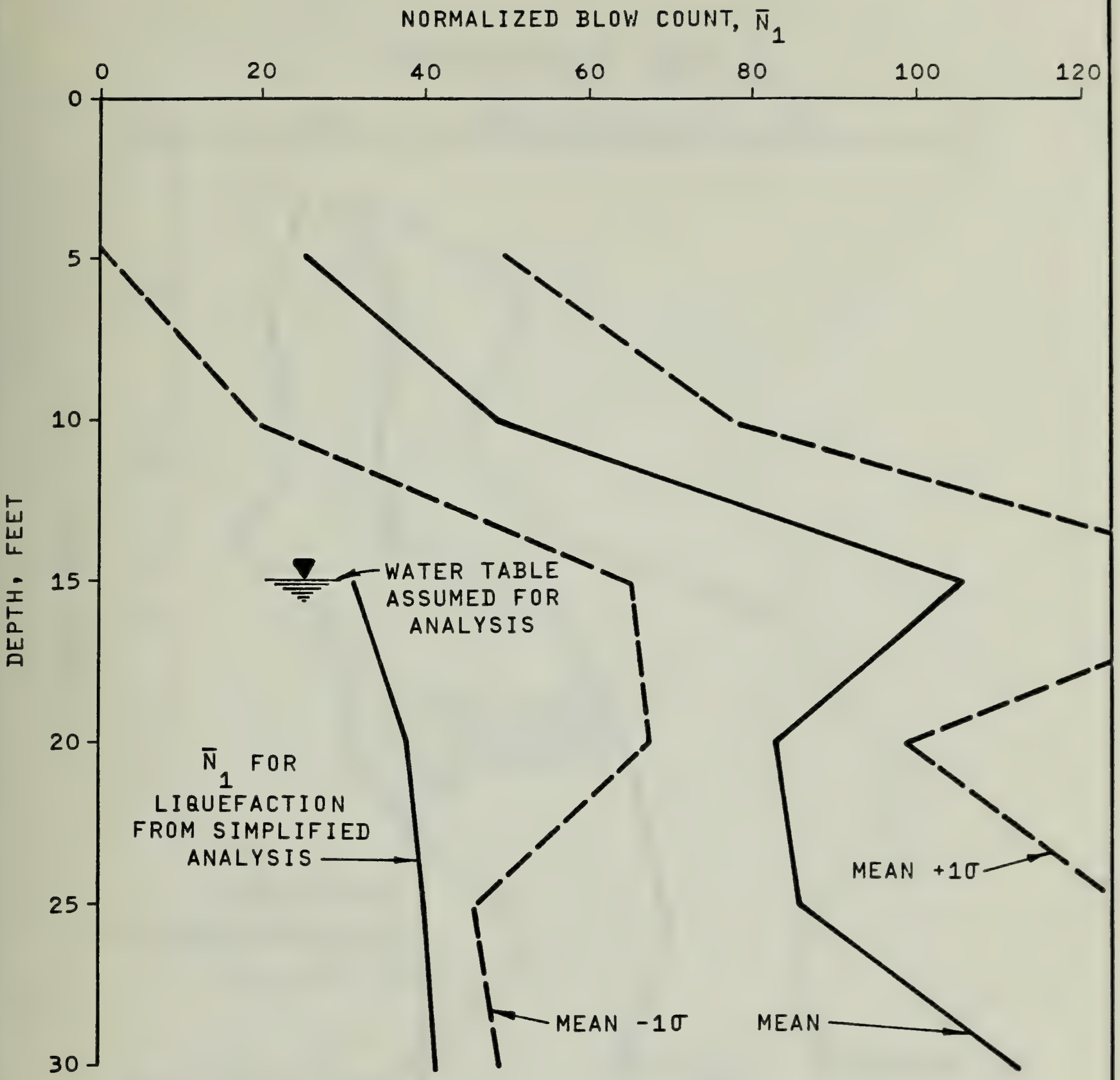
**DAMES & MOORE**

PEAK SOIL COLUMN RESPONSE TO HORIZONTAL BASE MOTION

| | 200 foot Profile | 150 foot Profile | 50 foot Profile | Rock Outcrop |
|---|---|---|---|---|
| 1) Golden Gate Park Record (Max. Acceleration = 0.13g) | | | | |
| a) Peak Acceleration at Ground Surface | 0.17g | 0.27g | 0.32g | 0.13g |
| Peak Acceleration at 20 foot depth | 0.03g | 0.11g | 0.13g | |
| Peak Acceleration at 100 foot depth | 0.09g | 0.12g | | |
| b) Peak Strain at Ground Surface | 0.004% | 0.007% | 0.009% | |
| Peak Strain at 20 foot depth | 0.033% | 0.045% | 0.036% | |
| Peak Strain at 100 foot depth | 0.027% | 0.028% | | |
| 2) Golden Gate Park Record x 3 (max. acceleration = 0.39g) | | | | |
| a) Peak Acceleration at Ground Surface | 0.26g | 0.40g | 0.48g | 0.39g |
| Peak Acceleration 20 foot depth | 0.16g | 0.23g | 0.27g | |
| Peak Acceleration 100 foot depth | 0.20g | 0.37g | | |
| b) Peak Strain at Ground Surface | 0.007% | 0.011% | 0.015% | |
| Peak Strain at 20 foot depth | 0.063% | 0.061% | 0.106% | |
| Peak Strain at 100 foot depth | 0.07% | 0.105% | | |

# RESULTS OF THE ONE-DIMENSIONAL SOIL RESPONSE ANALYSIS

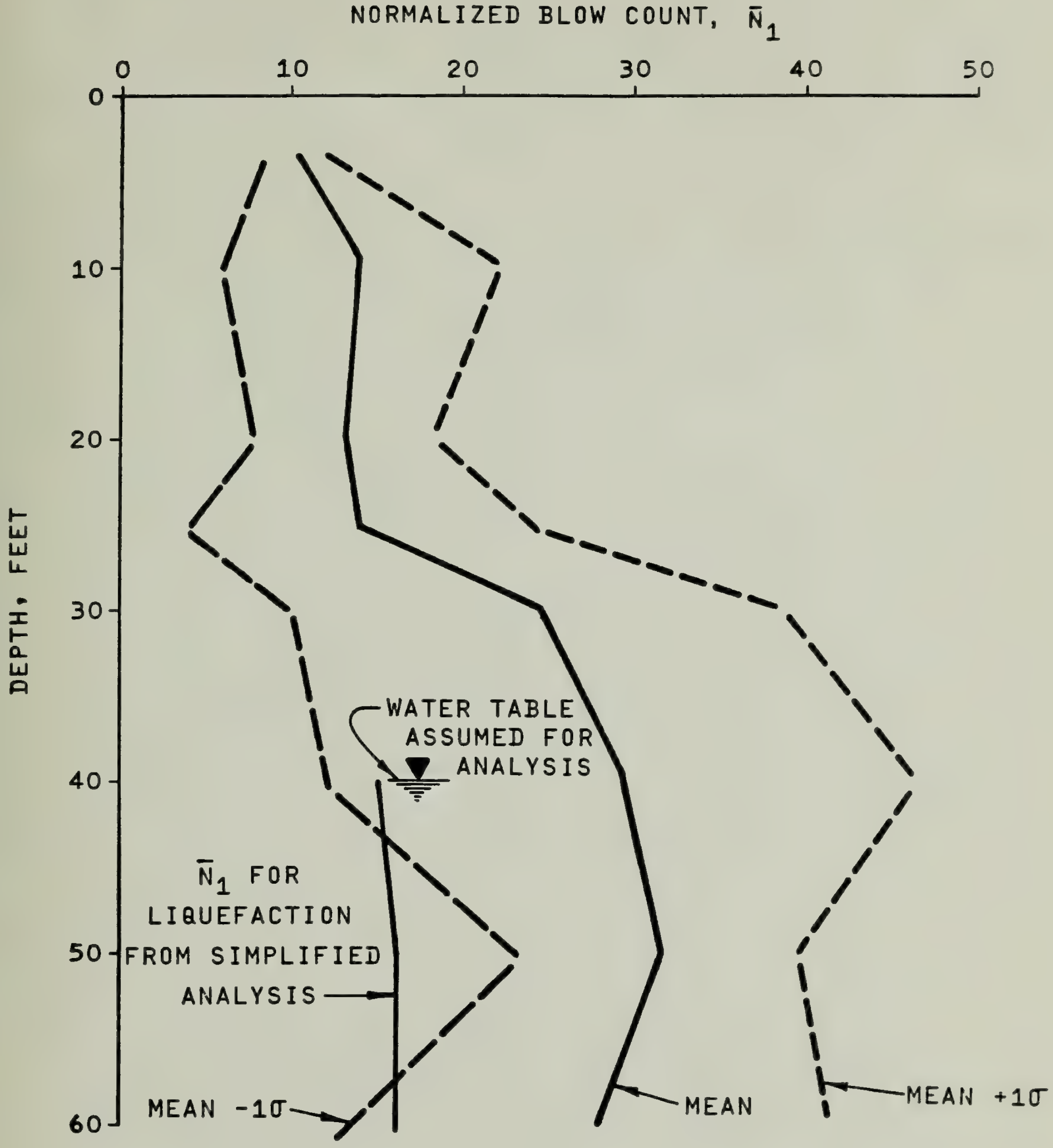
**DAMES & MOORE**



# LIQUEFACTION POTENTIAL AND NORMALIZED PENETRATION RESISTANCE VALUES FOR THE GREAT HIGHWAY AREA

(BLOW COUNT DATA BASED ON LEE AND PRASZKER, 1972)

DAMES & MOORE



## LIQUEFACTION POTENTIAL AND NORMALIZED PENETRATION RESISTANCE VALUES FOR FULTON STREET/NORTH GOLDEN GATE PARK AREA

DAMES & MOORE

PLATE 12B

# APPENDIX A

# SUBSURFACE SOIL & ROCK TYPES

## FIELD EXPLORATIONS AND LABORATORY TESTING

## A1.0 SOIL TYPES

A1.1 General - With minor exceptions the soil overlying bedrock may be classified into two main types, dune sand and Colma Formation sand. The occurrence of these soil types is widespread and is illustrated on the Subsurface Sections, Plates 5B through 5G. The location of the cross sections is shown on Plate 5A.

A1.2 Dune Sand - The surface layer of soil throughout essentially the entire site is dune sand. Its thickness varies from zero to over 150 feet, but it is most typically 40 to 80 feet thick. Dune sand is a light brown to yellow-brown poorly graded fine sand with none to a trace of fines.* It is cohesionless, medium dense to dense in its natural state, and may be classified as pervious (permeability of $10^{-3}$ cm/sec). Permeability test results are presented on Plate A-5. Below the water table it caves readily and will run into excavations unless fully restrained. The most notable characteristic of dune sand is its remarkable uniformity. The dune sand is expected to have similar properties regardless of where it is encountered in the study area. The range of particle size is very narrow, as shown on Plate A-4A, predominantly between 0.2mm and 0.3mm in diameter.

Dune sand does not normally contain natural obstructions such as boulders, and occurrences of impervious lenses such as clay pockets are extremely rare. Based upon a total of 32 strength tests, dune sand has an average angle of internal friction of approximately 36 degrees with a standard deviation of about 3 degrees.

A1.3 Colma Formation Sands - The second major soil type is the Colma Formation sands. The borings indicate that the Colma sands generally underlie the dune sand throughout the study area except where dune sand directly overlies bedrock.

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*Fines are defined as soil particles which will pass a #200 sieve (0.08mm), about the smallest that can be seen with the naked eye.

The Colma sands are generally brown to reddish-brown, dense to very dense, and fine-grained. Unlike the clean dune sands, the Colma sands are generally somewhat silty or clayey in nature. The fines content is quite variable and commonly ranges from 3 percent to 30 percent. The median particle size is about the same as for dune sand, but the variation is somewhat greater, as shown on Plate A-4B.

In most of the borings, the upper three to ten feet of the Colma Formation was found to be quite silty or clayey with more cohesion than the deeper material. This clayey matrix completely fills the voids between the sand particles rendering the upper surface of the Colma Formation relatively impervious. Of 26 borings which encountered Colma sands, in only 3 borings was this clay-rich layer not found in the upper several feet of the formation.

Below the upper three to ten feet of Colma material, the sands are more commonly silty rather than clayey in nature with a variable fines content. The Colma Formation has a distinctive horizontal bedding and occasional layers of clayey sand were encountered, as were other cleaner layers with only three to five percent fines. Because of the variability of fines content found in the Colma sands, it is expected that excavation would encounter zones of greater or lesser permeability in an unpredictable manner. Laboratory Tests of Colma samples indicate a range of permeability from $10^{-3}$ cm/sec to $10^{-8}$ cm/sec, as shown on Plate A-5.

Based upon a total of 38 tests, Colma sand has an average angle of internal friction of about 37 degrees with a standard deviation of about 4 degrees.

Colma sand does not ordinarily contain any obstructions such as boulders. However, in one or two instances layers of colluvium were encountered within the formation and colluvium may contain boulders.

In several borings and in certain outcrops, Colma sands display seams of weak cementation by reddish brown iron oxide. The cementation is most prevalent in the upper 20 feet of the formation and occurs in thin banded

layers. In Boring 26 the cementation and silty-clay binder was pervasive enough to permit coring. The strength of cementation is such that it can be easily broken with the fingers.

A1.4 Minor Soil Deposits - Several minor soil types were encountered in addition to dune sand and Colma sand. They are considered to have a minor engineering significance for tunneling construction in the Northerly or Direct Routes, but not for the South Route.

A1.4.1 Colluvium (Slope Wash) - Most of the borings encountered several feet of colluvium immediately overlying the bedrock, although in Boring 18, 40 feet of colluvial material was found. This material is a light brown or yellow fine sandy clay or clayey sand with varying amounts of rock fragments. Its consistency is generally very stiff to hard, and it is relatively impervious. It is possible that colluvium may contain boulders although none was encountered in the test borings.

A1.4.2. Beach Sand - Minor layers of beach sands were encountered in a few borings, most notably at about Elevation 0 in Boring 15. This occurrence may be a sand-filled sea cave. Other traces of beach sand found are considered to be localized, discontinuous deposits. It is probable that beach sand is present under the Great Highway. Beach sand is similar to dune sand in physical characteristics, but slightly coarser and better graded from fine- to medium-grained sizes. It is cohesionless and we estimate its permeability to be approximately $10^{-2}$cm/sec.

A1.4.3 Lagoon Deposits - Borings 1,3, and 7 encountered a thin deposit of gray-black or greenish-black silty clay at the contact between dune and Colma sand. The clay is plastic and stiff or very stiff. These layers are probably discontinuous lagoon or marsh deposits. In other borings the upper several feet of the Colma Formation was also noted to be colored dark gray or black, probably as a result of past inundation, but this coloration is not thought to have an engineering significance. These lagoon deposits are relatively impervious and may be moderately compressible.

A1.4.4 Manmade Fills - The only manmade fills known in the study area which may be of significance to this project are in the highway embankment where Lincoln Boulevard crosses Lobos Creek, and along the Great Highway in the former Playland-At-The-Beach area. In neither case were test borings drilled to determine the nature of the soil making up the fill. It is our preliminary opinion that the fill is composed of dune sand, possibly contaminated with natural or manmade debris. Its density is not known, but may be less than naturally occurring dune sand. In both cases it is possible that old concrete footings from demolished structures may be present.

## A2.0 BEDROCK TYPES

Two bedrock units and eight bedrock types have been recognized in the Richmond District. These units and rock types include:

FRANCISCAN ASSEMBLAGE

- Graywacke
- Interbedded Siltstone and Shale
- Serpentine
- Greenstone
- Chert
- Melange
- Limestone

GREAT VALLEY SEQUENCE

- Sandstone
- Interbedded Siltstone and Shale

The structural relations among these rocks are discussed in Section 2.5 of the main report, Site Geology. Data from detailed mapping along the coastline and Lincoln Park, together with borings for this and previous studies, have been compiled into geologic maps and an interpretive geologic profile on Plates 6A, 6B and 6C.

A2.1 Franciscan Assemblage. Seven rock types of the Franciscan Assemblage were encountered at the site: 1) graywacke; 2) interbedded siltstone and shale; 3) serpentine; 4) greenstone; 5) chert; 6) melange; and 7) limestone. Metamorphic rocks of the blueschist facies have been identified by Schlocker (1974) in exposures off the coast but this rock type was not encountered during this study. It is possible, however, that rocks of this composition might be encountered along the tunnel route, especially in melange zones.

A2.1.1 Graywacke - The graywacke in this locality is a well indurated, fine to medium grained sandstone. It is composed primarily of angular grains of quartz, feldspar, biotite and rock fragments and contains at least 15 percent clay matrix. Bedding is generally massive, on the order of three to ten feet in thickness; siltstone and shale interbeds and laminations occur locally. The graywacke typically weathers to a buff or light brown color near the bedrock surface, grading to gray where it is fresh. In some cases the graywacke is highly fractured (brecciated).

Bedding in graywacke west of Phelan Beach dominantly strikes N10W to N10E and dips 20 to 60 degrees to the east, the average dip is approximately 40 degrees. Bedding in graywacke east of Phelan Beach dominantly strikes N40-60W and dips 25 to 65 degrees to the south. Rose diagrams of bedding orientation are presented in Plates 7A and 7C.

The graywacke contains both joints and fault planes. The joints and fault planes are generally smooth, unweathered and typically contain clayey material. Old joints have commonly been cemented by calcite and often have been offset by younger displacements.

A tunnel is cut into the graywacke along the northern portion of Lands End. This tunnel is 4.5 to 6 feet high and 3 to 4 feet wide, and exhibits no appreciable areas of caving and/or sloughing in the graywacke. The tunnel is unlined and has remained intact since the late 1800's.

One hundred and thirty-nine point load tests were conducted on the Franciscan graywacke. The results are presented on the Geologic Logs at the appropriate depth, and a summary of the test results is presented on Plate A-8A. The variation in strength of the graywacke is primarily a function of its proximity to shear zones. The low to very low values obtained were near shear zones and the high to very high values were on fresh graywacke remote from shear zones. Compressive strengths shown on the detailed Geologic Log of Boring 13 illustrate the weakening of graywacke near shear zones.

Changes in the character of the graywacke with increasing proximity to shear zones is also reflected in the RQD (Rock Quality Designation: the percentage of a particular core run represented by fragments of core greater than four inches in length; see section A4.7). The RQD is commonly between 60 and 90 percent but drops to between zero and 25 percent near shear zones.

Core recovery in the graywacke was excellent - averaging about 90 percent.

A2.1.2. Interbedded Siltstone and Shale - Interbedded siltstone and shale units separate the massive graywacke beds of the Franciscan. The siltstone is highly indurated and usually less than three inches thick. The shale is softer and exhibits high fissility.* The shale beds are generally less than six inches but may measure a foot in thickness. Thin graywacke interbeds occur locally. The shale and siltstone are typically brown to olive brown where weathered, grading dark gray or black where fresh.

The interbedded siltstone-shale sections are usually less than four feet in thickness but sections have been measured up to 30 feet in thickness. Although thinner laminations of siltstone or shale may be present at closer intervals, the major interbeds commonly occur within the graywacke at intervals of between 20 and 30 feet.

Because of the weaker properties of the siltstone and shale interbeds relative to the graywacke, faults are commonly observed to occur in or very near the siltstone-shale units. Where intersected by a fault, the dip of the interbeds steepens rapidly toward the fault. Caving along the coastline is commonly observed where the siltstone and shale interbeds intersect faults.

Three point load tests were conducted on siltstone-shale units of the Franciscan. In general these samples were weak to very weak, as shown on Plate A-8B.

RQD ranged from zero to 25 present and was usually near zero. Core recovery averaged about 70 percent.

The shales have a high susceptibility to slaking based on laboratory observation.

A2.1.3. Serpentine - Serpentine is a green to black rock which is generally highly sheared and very weak but contains occasional extremely hard inclusions. It is formed by hydrothermal alteration of ultrabasic rocks. During this alteration, the rock expands about 40 percent by volume. It

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*Fissility: A property of being very thinly laminated and splitting easily parallel to the laminations.

is this expansion as well as emplacement along fault planes which causes it to be highly sheared.

Serpentine occurs primarily along faults and in shear zones. Inclusions of unsheared and unaltered serpentine up to 40 feet in size occur locally. These inclusions are generally surrounded by a sheared serpentine matrix.

Seven point load tests were conducted on serpentine. A summary of this data is shown on Plate A-8C. The bimodal distribution of very low and high values represent highly sheared serpentine and slightly sheared and altered serpentine respectively.

The RQD was generally near zero percent for sheared serpentine and close to 100 percent for the unsheared serpentine. Core recovery was generally around 40 to 50 percent.

Sheared serpentine has a moderate to high susceptibility to slaking based on laboratory observations.

A2.1.4 Greenstone - The greenstone in the study area is a dark green (fresh) to red brown (weathered) alteration product of submarine basaltic flows, sills, and pyroclastic deposits. In outcrop the greenstone is massive, very hard and commonly contains highly siliceous bands and veins. In the borings the greenstone is generally highly fractured and greenstone breccias occur commonly. Greenstone occurs primarily in the melange zones, often as large clasts and tectonic slabs. Greenstone may compose up to 60 percent of the thrust sheet-melange complex.

Seven point load tests were conducted on greenstone; Plate A-8D presents a summary of these tests. In general the data shows low to medium strengths. These low values are in part due to the highly fractured and brittle nature of the greenstone core.

In the massive greenstone, the RQD and core recovery are generally around 100 percent. In the highly brecciated zones and near shear zones, the RQD is generally near zero percent and the core recovery is zero to 40 percent.

A2.1.5 Chert - Chert is a red to green, banded, highly siliceous rock. It is generally thinly bedded (1 to 4 inches) and highly folded. Rarely, massive inclusions up to 6 to 10 feet in size have been observed.

Chert generally occurs in close association with greenstone and commonly is fractured.

The 1938 Richmond sewer tunnel (see Plate 2) was reported to have penetrated up to 2,000 feet of "red rock chert" (Rothschild, 1938). Tunneling was quite rapid and it is noted that in places it was unsupported; however, this is a relatively small tunnel.

The RQD of the thinly bedded chert is generally less than 70 and commonly zero percent. Core recovery averages around 5 to 20 percent, probably due to the thin bedding and common fractures.

A2.1.6 Melange - Melange is ususally defined as a heterogeneous assemblage of rock fragments of varying types and sizes which float in a less coherent, often sheared, matrix. In the study area the melange is more a tectonic unit than a lithologic unit; that is, it is the result of tectonic mixing-folding, faulting, brecciation, etc. Three melanges have been identified in the Richmond District: 1) the Phelan Beach shear zone; 2) the thrust sheet complex; and 3) the City College Fault Zone.

Exposures of melange comprising the Phelan Beach shear zone occur at Phelan Beach and samples were obtained from Boring 27. The observed inclusions consisted of serpentine, chert, limestone, graywacke, siltstone and shale. Clasts generally ranged from pebble to boulder size. The matrix was composed of sheared, dark gray shale.

Exposures of melange comprising the thrust sheet complex occur in the cliffs along the coast east of Land's End. Samples were obtained from Borings 13, 20, 22, 23, 28 and 30. Inclusions were composed primarily of greenstone and graywacke with some chert. It is believed that many of these inclusions are actually large slabs, commonly several hundred feet in greatest dimension. From exposures and the borings, it would appear that the zone is dominated by large inclusions with relatively little matrix. Borings 28 and 30 in the immediate proximity of the proposed tunnel alignment, however, show a greater proportion of matrix. The inclusions are commonly more highly fractured and in these two borings, range up to 70 feet in thickness. On the basis of outcrops and borings, inclusions compose at least 60 percent of the thrust sheet-melange complex and may compose up to 80 percent.

Exposures of melange comprising the City College Fault Zone occur along the coast west of Land's End. Samples were obtained from Borings 16, 17 and 32. The clasts were found of Franciscan graywacke, serpentine, greenstone and chert, and Great Valley Sequence sandstone and interbedded siltstone and shale. Examination of exposures indicate that about 60 percent of the melange is clay-shale matrix and 40 percent inclusions. We estimate that about 20 percent of the melange zone is composed of inclusions which exceed ten feet in size.

The matrices of the melange zones described above are generally composed of medium to dark gray sheared shale which is commonly highly slickensided and locally serpentinitic. This matrix material generally exhibits a high susceptibility to slaking. Emission spectrographic analyses were performed on three samples to determine the chemical composition of the matrix. X-ray diffraction patterns were also run on these samples to evaluate the mineralogy. Swell pressure tests were conducted by our laboratory to evaluate potential swell pressure development in the clays.

The semi-quantitative emission spectrographic analyses show chemical compositions dominated by silicon, aluminum and magnesium with notable amounts of iron, calcium and sodium. Little or no potassium is present. The results of these tests are presented in Plate A-7.

The X-ray diffraction patterns indicate that the clay fraction of these shales is dominated by a variable-spacing smectite-like or mixed layer mineral, possibly montmorillonite-vermiculite, with lesser amounts of kaolinite and illite. The non-clay mineral phase of these shales is dominated by quartz, with lesser amounts of feldspar. Organic matter and carbonate are generally absent.

The swell pressure tests indicate that the shale of the melange matrix shows a slight to moderate tendency to develop swell pressures when restrained The results of these tests are presented in Plate A-6. Testing procedures are described in Section A4.5.

The RQD of the shale matrix is generally very high, however for such very weak material the RQD loses its significance as a classification parameter. The core recovery ranges from zero to 100 percent and is most commonly

in the range of 50 to 75 percent due to the cohesive properties of the clays.

A2.1.7 Limestone - Limestone has been identified in the Richmond District only in the Phelan Beach melange zone. The limestone is dark gray to black, dense, and fine to medium grained. It occurs as several clasts, 10 feet in size, on the beach. On the basis of this observation, limestone clasts are considered most likely to occur along the tunnel route in the Phelan Beach melange zone, however limestone may also be present in the other melange zones.

A2.2 Great Valley Sequence - In the Richmond District, two rock types have been identified as part of the Great Valley Sequence: 1) sandstone; and 2) interbedded siltstone and shale.

A2.2.1 Sandstone - The sandstone is white to medium gray, medium grained, and very strong. It is relatively rich in potassium feldspar and contains numerous siliceous veins. From exposures along the coast it appears that the sandstone is generally massive and that lenses of interbedded siltstone and shale within the sandstone are relatively uncommon. Data from Boring 15 and the report of the construction of Mile Rock sewer tunnel (Taylor, 1916), however, suggest that shale interbeds may be more common than observed in outcrops. Shear zones in the sandstone are relatively rare, and most joints and fractures have been cemented with siliceous veins.

Several tunnels, up to eight feet in diameter, have been excavated in the Great Valley sandstone in the vicinity of Sutro Baths. No evidence of sloughing was found in any of these tunnels, which have remained unlined since the late 1800's. Portions of the Mile Rock Sewer tunnel (under 48th Avenue, see Plate 2) were excavated in sandstone. The rock was reported to be very hard and no timbering was required (Taylor, 1916).

Fifty three point load tests were conducted on the sandstone of the Great Valley Sequence. A summary of this data is shown on Plate A-8E.

The RQD of the sandstone was generally near 100 percent except near shear zones where the RQD dropped to zero to 25 percent. Core recovery was commonly close to 100 percent.

A2.2.2 Siltstone and Shale - The siltstone and shale of the Great Valley Sequence are quite different from those of the Franciscan Assemblage. The siltstone is light gray to white, highly siliceous, hard, and contains siliceous veinlets. The shale is light to dark gray and does not exhibit fissility except near shear zones. Bedding thickness varies but is generally less than two to three inches for the siltstone and less than two feet for the shale. The bedding is highly convoluted and folded; the rock, however, still appears to be quite hard and medium strong.

Semi-quantitative emission spectrographic analyses were performed on one shale sample from the Great Valley Sequence. This analysis shows a chemical composition dominated by silicon, aluminum and iron with notable amounts of potassium, sodium and magnesium. A distinguishing feature of this composition is the relative enrichment in potassium, and to a lesser degree in sodium, as compared to the shales of the Franciscan Assemblage. The results of these analyses are presented on Plate A-7.

X-ray diffraction patterns were also obtained on this sample. This shale had a much less complex clay mineralogy than the shales tested of the Franciscan Assemblage. The dominant clay minerals are illite and kaolinite.

The Mile Rock sewer tunnel appears to have been excavated largely through interbedded siltstone and shale of the Great Valley Sequence. Timbering was required but no unusual difficulties in tunneling were reported (Taylor, 1916).

Fourteen point load tests were conducted on siltstone and shale samples of the Great Valley Sequence. A summary of these tests is presented on Plate A-8F. The results are centered around the medium strength range. Generally the higher values represent more silty samples and the lower values more shaley samples.

The RQD for the interbedded siltstone and shale ranged from zero to 65 percent and was most commonly around 25 percent. Core recovery ranged from 3 to 98 percent and averaged around 60 percent.

## A3.0 FIELD EXPLORATIONS

### A3.1 Geological Reconnaissance

The geological field explorations consisted of mapping all bedrock exposures in the study area and conducting a limited magnetic survey in Lincoln Park.

The geologic reconnaissance and mapping was conducted by geologists from our office assisted by our consultants, Logistics International Consultants of San Francisco. The field work was not conducted all at once, but at various times during December 1977 and throughout 1978. This was because the need for additional study of selected areas only became apparent as the geologic map of the study area evolved. The major portion of the geologic reconnaissance was conducted along the cliffs on the north and northwest sides of the study area, including several existing minor tunnels and other excavations in the bedrock. Standard geologic practice and nomenclature was used in the recording of strikes and dips, joint patterns, and other structural features. The position in the field was usually determined from large-scale aerial photographs and transferred to topographic maps of the same scale.

The results of the reconnaissance are shown on the Geologic Map of the Western Richmond District, Plate 6A. An interpretive extrapolation of the field data plus information from the test borings was made to prepare the Interpretative Geologic Map at invert level, Plate 6B, which depicts the estimated configuration of the general types of bedrock as they might appear if the soil and rock cover were stripped off to invert level in the study area. A similar interpretive extrapolation was made to prepare the Geologic Section Along the Preferred Route, Plate 6C.

The magnetic survey was conducted in Lincoln Park. The survey was conducted by two geologists from our office using a portable proton magnetometer, GeoMetrics Model G-816. Data points were spaced at approximately 20 foot intervals. Location in the field was controlled by measuring tape and a large-scale aerial photograph.

## A3.2 Drilling and Sampling Program

Information about the subsurface soil and rock conditions throughout the study area was obtained by drilling 33 small diameter (3 to 6 inches) test borings at the locations shown on the Site Plan, Plate 1. The boring program was conducted in three phases: Phase One, covering the period of December 5, 1977 through January 24, 1978 during which Borings 1 through 19 were drilled (Boring 13 in part only); Phase Two, from March 14, 1978 through April 21, 1978, during which Borings 20 through 24 were drilled and Boring 13 completed; and Phase Three, from July 5, 1978 through August 25, 1978, during which Borings 25 through 33 were drilled.

Our primary drilling subcontractor was the J.N. Pitcher Drilling Company of Daly City, using truck-mounted conventional rotary-wash type drilling equipment. The HEW Drilling Company of Mountain View was also engaged for portions of Phase One (Borings 1 and 2 in part, Borings 5 and 8 entire) and Phase Two (Boring 24). HEW utilized truck-mounted equipment which combined hollow-stem auger and rotary-wash drilling methods. A third drilling company was also used for Phase Two. The Continental Drilling Company of Madera drilled Boring 23 using truck-mounted rotary-wash equipment which included a wire-line apparatus for more efficient rock coring operations.

All of the borings were drilled with a biodegradable (Revert) slurry except Borings 32 and 33 for which a bentonite slurry was used. Borings 32 and 33 were simple probes, drilled solely for the purpose of determining the type of bedrock present at the boring locations. They were not advanced to the tunnel level, but only to elevations +177 and +203 feet respectively. All of the other borings were advanced to at least one tunnel diameter below invert level with the exception of Boring 17. Boring 17 had to be abandoned at elevation +118 feet due to continual caving of the hole which the drillers were unable to control. It is our opinion, however, that rock conditions from elevation +118 to well below invert level would be similar to the rock encountered above elevation +118: sheared shale melange with random tectonic inclusions of various rock types.

Location in the field was controlled by tape measure from street corners, curb lines, or other fixed landmarks. In most instances, the surface elevation at the boring location was based upon the official city grade at the nearest street intersection as supplied by the City. Official city grade may differ slightly from the true ground surface elevation. Where an official city grade was not established reasonably close to a boring location, the surface elevation was referenced to the nearest surveyed mark as recorded with the City Surveying Department. The method of elevation control used is noted on each Log of Boring.

All drilling operations were conducted under the direction of a member of our technical staff or of our consultants, PSC and Associates of Mountain View and LIC Georesources of San Francisco. A continuous field log of each boring was maintained, based upon recovered samples, behavior of the drill rig, and observance of the soil or rock cuttings being flushed out of the hole by the drilling fluid. Both disturbed and undisturbed samples of the soil and rock strata encountered were obtained for examination, classification, and laboratory testing.

All samples recovered during our field exploration program were transported to our laboratory in San Francisco for further examination and testing. Based on the results of our field data and subsequent laboratory test results, detailed Logs of Borings were prepared. These Logs of Borings are presented on Plates A-1A through A-1AG. Where appropriate, detailed geologic logs follow the regular Log of Boring. Soils were classified in accordance with the Unified Soil Classification System, described on Plate A-2A, Soil Classification Chart and Key to Test Data. Rock types were classified in accordance with the lithographic classifications presented on Plate A-2B, Rock Classification Chart and Key to Geologic Logs. Explanations of the nomenclature and symbols presented on the Logs of Borings are also presented on Plates A-2A and A-2B.

Sampling of the soil and rock was accomplished by various methods as noted at the sample elevation on the Logs of Borings by the appropriate symbol, defined on Plate A-2A.

Relatively undisturbed soil samples were recovered using the Dames & Moore Type-U Sampler, illustrated on Plate A-9; the thinwall attachment was used where possible to minimize sampling disturbance. The sampler was advanced using different techniques depending on the type of drilling equipment being employed. When rotary-wash drilling equipment was used, the U-Sampler was driven with down-hole slipjars of varying weight falling from varying heights. When hollow stem auger drilling equipment was used, the sampler was driven with a 140-pound hammer falling 30 inches. The specific method of driving the U-Sampler is noted on each Log of Boring. The sampling resistance, measured in blows per foot of sample penetration, or fraction thereof, is shown on the Log of Boring adjacent to the appropriate sample.

In cohesionless soils, Standard Penetration Tests (SPT) were also performed during the field exploration program. These tests utilized a 2-inch OD, 1-3/8-inch ID Sampler driven with a 140-pound hammer falling 30 inches, in accordance with ASTM Test Designation D-1586-64T. Sampling resistance was used as an indication of the relative density and an approximate measure of the strength of the cohesionless soils. The sample recovered by the SPT test is disturbed.

Occasionally, disturbed samples were obtained by simply collecting a quantity of cuttings without the use of a sampler. Such samples, used for classification purposes only, are noted on the Logs of Borings as "grab" samples.

Where the soil was too hard to sample with a drive sampler, a Pitcher Tube Sampler was used. The Pitcher Tube Sampler is illustrated on Plate A-10. It recovers an undisturbed sample by pushing a non-rotating, spring-loaded tube against the bottom of the borehole, while at the same time drilling out the surrounding soil with a hollow saw-tooth bit.

Highly weathered or fractured rock was sometimes sampled with a U-Sampler or a Pitcher Tube Sampler, but for the most part bedrock was sampled with a diamond bit double-tube NX (2-1/8-inch inside diameter) core barrel, either 5 or 10 feet long. In general, while drilling or coring rock the

circulating drilling fluid was sieved to collect cuttings from each foot of drilling. Due to budgetary limitations and the great depth of rock to be penetrated in some cases before approaching the tunnel level, continuous coring from the rock surface was not always practical, and intermittant core runs at intervals of 20 feet or more were taken. Under these conditions, and also when core recovery was poor, the cuttings collected from each foot were examined and classified to supplement the recovered core samples in preparation of the Log of Boring. As a further aid in evaluation of the rock conditions, the drilling and coring rates (minutes per foot) were recorded. The recorded rates may be helpful in comparing consecutive feet but no attempt should be made to correlate different borings or even different core runs in the same boring on the basis of drilling rates, as there are many variables besides rock hardness which may influence the observed rate: down-pressure, bit type and wear, fluid pressure, rotational speed, and operator skill.

Piezometers were installed in all borings except Borings 17, 32, and 33 to permit long-term measurement of the ground water level. Piezometer installations consisted of 1-inch-diameter PVC plastic pipe, perforated in the lower 20 feet. The annular space between the pipe and the borehole wall was backfilled with coarse sand or pea gravel. In rock strata, a bentonite seal was placed at about one tunnel diameter above the tunnel crown level. In soil strata, the bentonite seal was located to coincide with an impermeable soil layer, usually the top of the Colma Formation. Where no impermeable layer was found above tunnel level, the bentonite seal was omitted. In Borings 11, 25, and 26 two piezometers were installed, one in dune sand above the surface of the Colma Formation and one below the surface of the Colma Formation. In Boring 11, identical water levels were measured in both tubes. In Boring 25, the piezometer in the dune sand is dry while the lower piezometer has a water level well above the surface of the Colma Formation. This might be indicative of an artesian condition in the Colma Formation, however the piezometer appears to be unresponsive to intentional changes in its water level. This fact, together with the much deeper readings from adjacent Borings 24 and 26, suggest that the piezometer somehow

became blocked during installation and is not functioning properly. In Boring 26, the piezometer in dune sand is dry and the one in Colma sand has a water level of about elevation +53 feet. Boring 13, which was drilled to elevation +103 during Phase One and advanced to elevation zero during Phase Two, recorded two water levels. After Phase One, the boring was left open and a water level of elevation +334 feet was measured. During Phase Two, a piezometer was installed and now has a water level of about elevation +96 feet. It is probable that the former reading represents a perched water table in the thin soil mantle over bedrock; however, this has not been corroborated by water level readings from any of the other borings. The recorded water levels are indicated on the Logs of Borings and where there has been a slight variation over the long term, two levels are shown to indicate the range of variation measured.

## A4.0 LABORATORY TESTING

### A4.1 General

All samples recovered during the field exploration program were visually examined and classified in our laboratory, and laboratory tests were performed on selected representative soil and rock samples. The laboratory testing program was designed to provide data for the evaluation of the physical properties and engineering characteristics of the subsurface soils and rocks. The program included determinations of soil and rock classification indices, shearing strengths, swelling characteristics, permeabilities, and special analytical tests. The types of tests performed are described in the following paragraphs.

### A4.2 Classification Tests

#### A4.2.1 Moisture and Density

Moisture contents and dry densities (MD) were determined on selected, relatively undisturbed soil samples, and moisture contents (M) were determined on selected disturbed samples, to aid in defining the interface between various soil layers and correlating the layers between the borings. These tests were also used to evaluate the overburden soil pressures for use in soil pressure analyses. The tests were performed in accordance with the ASTM Test Designation D-2166-66. Test results are tabulated on the Logs of Borings adjacent to the appropriate samples.

### A4.2.3 Mechanical Analysis

As an aid in classifying samples, to provide information on the particle size and gradation of the soil types at the site, and as an indicator of the permeabilities of the soil layers, Sieve Analyses (SA) were performed on representative samples. These tests were performed in accordance with ASTM Test Designation D-422-63. The gradation curves are presented on Plates A-3A through A-3AA, Grain-Size Distributions. The percentage of sample smaller than the #200 sieve is tabulated on the Logs of Borings adjacent to the appropriate sample. In addition, all sieve tests on dune and Colma sands were grouped together and the median grain-size distribution and standard deviation computed. The results, Summary Grain-Size Distribution, are shown on Plate A-4A for dune sand and plate A-4B for Colma sand.

## A4.3 Strength Tests

### A4.3.1 Direct Shear, Consolidated-Drained

To evaluate the effective strength characteristics of the dune and Colma sand deposits, consolidated drained direct shear tests (DS/CD) were performed on representative samples of these granular materials. To insure that the samples were tested under approximately natural conditions, those samples recovered from above the ground water table were tested at field moisture while those samples which were recovered below ground water level were saturated prior to testing. All samples were tested at confining pressures which approximated the effective natural overburden pressure. The test results are tabulated on the Logs of Borings adjacent to the corresponding samples. The method of performing the consolidated, drained direct shear tests is described on Plate A-11.

### A4.3.2 Unconfined Compression

To provide data on the cohesive strength of stiff clayey colluvial soils and residual clay soils, unconfined compression tests (UC) were performed on naturally saturated samples of these soils. The tests were performed in accordance with ASTM Test Designation D-2166-63T. The method of performing the test is shown on Plate A-12 and the test results are indicated adjacent to the samples on the Logs of Borings.

### A4.3.3 Triaxial Compression, Consolidated-Undrained

To provide compressive shear strength data on stiff cohesive samples of colluvium, residual soil, sheared shale melange, and gouge material, several consolidated undrained triaxial compression tests (TX/CU) were performed on saturated samples of these soils from Borings 22, 27, and 31. The samples from Boring 27 are the same ones used for the swell tests, described below. The method of performing the test is shown on Plate A-12, and the results are indicated adjacent to the corresponding samples on the Logs of Borings.

### A4.3.4 Point Load Tests

The compressive strength, CP, of sound rock core was indirectly computed on the basis of tensile failure induced by the point load test. In essence this test involves compressing a rock specimen between two points and computing a point-load index, $I_s$, which is calculated as the ratio of the applied load P to the square of the distance H between the loading points ($I_s=P/H^2$). The loading "points" or platens are of a standardized conical shape with rounded points.

The point load test is an indirect tensile test, which means that the vertical concentrated applied load creates a horizontal tensile stress and failure eventually occurs by splitting along a plane or planes which run parallel to the direction of load application. Because of this, the point load index may be correlated with the tensile strength as well as with the compressive strength of rock by a conversion factor, K. For conversion to the uniaxial compressive strength, $CP=KI_s$ where K is related to the diameter, D, of the specimen by $k=4.7D + 13.5$ (after Bieniawski, 1974).

The results are indicated on the Geologic Logs adjacent to the sample tested. Two qualifying factors should be kept in mind when studying the compressive strength values derived from the point load tests. First, the tests were run on air-dried partially saturated samples which will test at a higher strength than their saturated counterparts. The strength increase produced by loss of moisture is probably from 10 to 25 percent, with the greatest effect occurring on the weaker and more argillaceous rocks. Second, the tests were only run on intact pieces of core at least 3 inches long. Thus where a test is indicated in a highly fractured or brecciated zone, the

strength recorded may be representative of the larger intact pieces of core but not of the rock mass as a whole, which may behave as a much weaker material.

## A4.4 Permeability Tests

Constant-head type permeability tests (PERM) were run on selected samples of dune and Colma sands. The consolidation pressure and head differential applied to the samples were chosen to simulate conditions at the tunnel level. Each test was run several times and the results shown on Plate A-5 are average values. No permeability tests were run on samples of rock as all of the rock types encountered have low permeabilities and it is our opinion that ground water movement in the bedrock will be controlled by the presence or absence of open cracks rather than by the permeability of the intact rock.

## A4.5 Swell Pressure Tests

In an attempt to evaluate the potential swell pressure which may be developed by the sheared shale bedrock, four samples from Boring 27 were subjected to swell pressure tests (SWELL). The tests were designed to simulate conditions of stress relief adjacent to the tunnel excavation, followed by the fully restrained conditions which would exist when the stiff concrete lining is poured directly against the excavated rock surface. The samples were first fully consolidated in a high-pressure triaxial test chamber. The confining pressure was then suddenly reduced to zero, simulating exposure of the rock to the open excavation. Next, to simulate the conditions which would exist with the rigid tunnel lining in place, the triaxial test chamber was sealed off, still without application of any external pressures on the sample. As the water surrounding the sample is essentially incompressible, zero-strain conditions were thus imposed, although the pore-water supply valve communicating through the ends of the sample was left open and unpressurized. At this point, the sample would in theory reveal any swelling tendencies by attempting to draw in pore water through the end caps while being held to zero strain by the sealed fluid-filled test chamber. The test then consisted of simply monitoring the chamber pressure over a period of time to determine the maximum swelling

pressure which the sample was capable of developing. The results are presented in Plate A-6. To evaluate whether there was any corrollation of the swell pressure with the Atterberg Limits or clay mineralogy, some of the swell test samples were subjected to these tests as well. The clay mineralogy tests were conducted under the supervision of Dr. J. K. Michell at the University of California at Berkeley using x-ray diffraction techniques.

### A4.6 Special Analytical Tests

During the test boring program, it was sometimes noted that a black "oily appearing" scum would slowly accumulate on the surface of the recirculating drilling fluid in the settling tank when shale was being cored. At no time was more than an ounce or two of this substance observed. As the Franciscan Assemblage is classified by the California State Division of Industrial Safety (Cal-OSHA) as "potentially gassy", it was decided that this unidentified substance should be analyzed in an attempt to determine whether or not it is a naturally-occurring petro-chemical substance which might be linked to the presence of dangerous gases. A sample was collected (which was unavoidably mixed with some silt and water).

Pacific Environmental Laboratories of San Francisco tested the substance for total solids, volatile fraction of the total solids (@ 500°C), and sulphate ($SO_4$) content, the latter to estimate whether sulpher was present in sufficient quantities to justify concern for the presence of $H_2S$ gas.

Analysts, Inc. of Oakland ran a spectrographic analysis of the substance for the purpose of identifying key elements associated with typical additives used in refined oil products, as there was a possibility that the substance was coming from the drill rig itself rather than from the borehole. Analysts, Inc. specialize in the analysis of used motor oils to evaluate the condition of both the oil and the engine in which it was used.

Elek Microanalytic Laboratories of Torrance tested the substance for total carbon and hydrogen content, first as received, and second after treatment with an acid solution to remove that portion of carbon which might be in the form of carbonates ($CO_3$). The purpose of this test was to provide an indication of whether the substance was primarily organic or inorganic. Elek also tested several shale samples in the same manner. In

addition spectrographic analysis of the shale samples was performed for the purpose of evaluating whether the substance was markedly different in composition than the shale or if it was, after all, simply finely ground shale or graphitic type material.

The results of all of these tests are presented on Plate A-7.

### A4.7 Rock Quality Designation

The Rock Quality Designation (RQD) is not actually a laboratory test, but rather a computed value used in making a general observation regarding the degree of fracturing or brecciation of the rock mass. The RQD is a single value (percent) computed for each core run by summing the lengths of all intact pieces of core 4 inches or longer and dividing this amount by the total length of the core run. It is implied in the computation that all core not recovered consisted of pieces shorter than 4 inches. Pieces longer than 4 inches but split by a vertical fracture were not counted as intact. The hardness or degree of weathering was not considered in the computation of RQD. Very poor rock such as sheared shale was considered intact and counted as such so long as there were no open fractures, regardless of how weak the material might be. Similarly, healed fractures, fractures or breccia cemented by clay, calcite or other minerals were considered intact and counted regardless of the strength of the joint. A full understanding of the significance of the RQD must therefore include knowledge of the rock type, strength, and structural defects. The RQD is graphically presented on the Geologic Logs for each core run. The RQD and percent recovery is summarized on the Generalized Geologic Profile of the Preferred Route, Plate 6C.

The following Plates are attached to and complete Appendix A:

| | |
|---|---|
| Plates A-1A through A-1AG | Logs of Borings 1 through 33 (Certain Logs of Borings are followed by Geologic Logs, indicated by /1, /2, etc. after the regular Log of Boring Plate No.) |
| Plate A-2A | Soil Classification Chart and Key to Test Data |
| Plate A-2B | Rock Classification Chart and Key to Geologic Logs |

| | |
|---|---|
| Plates A-3A through A-3AA | Grain-Size Distribution |
| Plate A-4A | Summary of Grain-Size Distribution, Dune Sand |
| Plate A-4B | Summary of Grain-Size Distribution, Colma Sand |
| Plate A-5 | Permeability Test Results |
| Plate A-6 | Results of Swell Pressure Tests on Sheared Shale Samples (Melange) |
| Plate A-7 | Analysis of Black "Oily" Appearing Substance Skimmed from Wash Water While Coring Franciscan Shale and Comparison with Shale Samples |
| Plates A-8A through A-8F | Summary of Point Load Data |
| Plate A-9 | Soil Sampler Type U |
| Plate A-10 | Diagrammatic Sketch of Pitcher Sampler |
| Plate A-11 | Method of Performing Direct Shear and Friction Tests |
| Plate A-12 | Methods of Performing Unconfined Compression and Triaxial Compression Tests |

# REFERENCES

Bieniawski, Z.T., 1974, "The Point Load Test in Geotechnical Practice", Engineering Geology, No. 9, pp. 1-11.

Rothschild, R.B., 1938, "Well Points Aid Driving of Small Tunnel in Wet Sand", Western Construction News, April 1938, pp. 143-145, (regarding the Richmond-Sunset Sewer Tunnel in San Francisco).

Taylor, C.M., 1916(?), "Mile Rock Tunnel - Final Report on Methods and Cost of Construction", Bureau of Engineering, City and County of San Francisco, (Report is located at the Department of Structural Engineering).

## EXPLANATORY NOTE TO GEOLOGIC LOGS

The key to the Geologic Logs is presented on Plate A-2B. However, three areas of potential confusion in interpreting the logs should be understood. These are explained below.

1) Blank zones in the Weathering, Strength and Fractures per Foot columns: To evaluate the Weathering, Strength, and Fracture per foot columns, one must first refer to the Lift and Core Recovery Column. If the core recovery is 100 percent, then the entire Weathering, Strength and Fractures per foot columns will be relevant. If they are blank that means that the rock is fresh, very strong and has no fractures per foot, respectively. However, if the core recovery for a given run is less than 100 percent, all three columns are blank where the field engineer assumed that the core loss occurred.

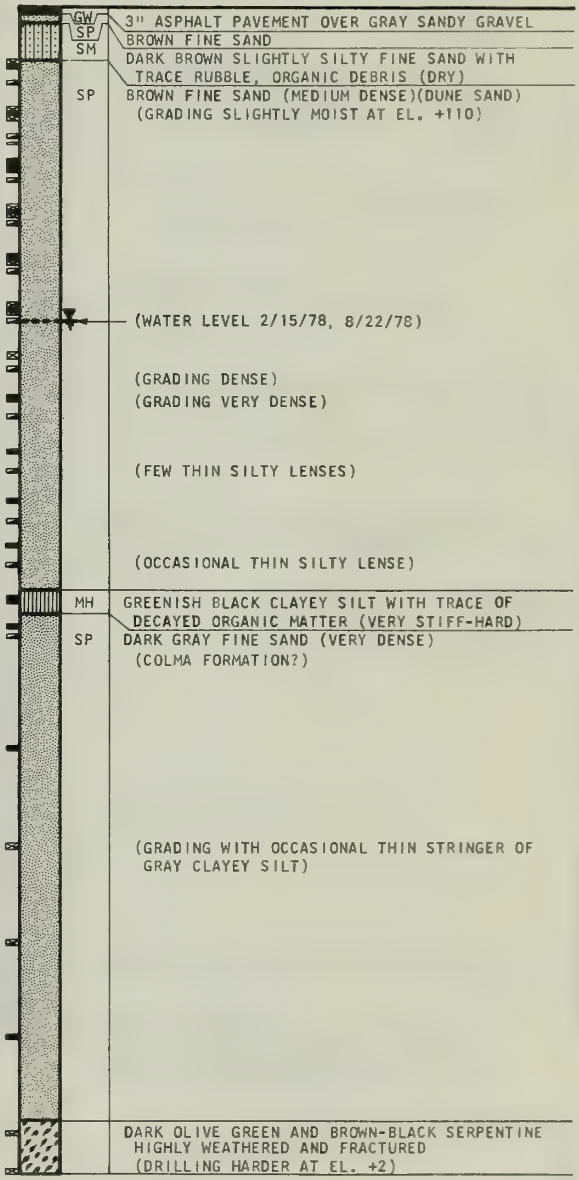
2) Interruptions in the Log: In areas where coring was not performed and the boring was advanced by tricone drilling, the log is often shortened. However, the graphic log has been continued based on inspection of cuttings.

3) RQD(Rock Quality Designation): The method of computing the RQD is explained in Section A4.7 of Appendix A. The RQD is an indicator of the degree of fracturing of the rock mass, but it is not related to the strength of the rock. Thus, if the core is intact, even very weak or highly weathered rock may have a high RQD percentage.

## BORING I
DRILLED 12/5-7/77

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS | | SHEAR STRENGTH TEST RESULTS | | | | | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD.PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | LIQUID LIMIT | PLASTIC LIMIT | LABORATORY | | | FIELD | | | | | |
| | | | | | | TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | TORVANE (PSF) | PENETROMETER (PSF) | | | | |
| +120 | | | | | | | | | | | | | | |
| | | 1 | 103 | | | | | | | | | U | 72 | 32 |
| | | | | | | | | | | | | SPT | 100 | 10 |
| +110 | | 2 | 99 | | | DS/CD | 1500 | 970 | | | | TW | 79 | 41 |
| | | | | | | | | | | | | SPT | 100 | 17 |
| | | | | | | | | | | | | GRAB | | |
| | | 2 | 120 | | | | | | | | | TW | 90 | 61/9" |
| | | | | | | | | | | | | SPT | 100 | 23 |
| +100 | | 3 | 107 | | | DS/CD | 2300 | 1940 | | | | TW | 100 | 66 |
| | | | | | | | | | | | | SPT | 100 | 18 |
| | | 2 | 113 | | | | | | | | | TW | 100 | 40 |
| | | | | | | | | | | | | SPT | 100 | 24 |
| +90 | | 7 | 104 | | | DS/CD | 3400 | 2450 | | | | TW | 100 | 38 |
| | | | | | | | | | | | | SPT | 100 | 16 |
| | | | | | | | | | | | | TW | 75 | 29 |
| | | | | | | | | | | | | SPT | 100 | 32 |
| +80 | | 22 | 102 | | | DS/CD | 4200 | 3120 | | | | TW | 89 | 47 |
| | | | | | | | | | | | | SPT | 67 | 55 |
| | | 15 | 108 | | | | | | | | | TW | 100 | 90 |
| | | | | | | | | | | | | SPT | 56 | 27 |
| +70 | | 17 | 107 | | | DS/CD | 4600 | 4200 | | | | U | 27 | 100/10.5" |
| | | | | | | | | | | | | SPT | 100 | 97/8.5" |
| | | 19 | 111 | | | | | | | | | U | 81 | 140 |
| | | | | | | | | | | | | SPT | 100 | 66 |
| +60 | | 147 | 34 | 124 | 110 | | | | | | | TW | 81 | 10 |
| | | 14 | 123 | | | | | | | | | U | 81 | 147 |
| | | | | | | | | | | | | SPT | 100 | 185/8" |
| +50 | | | | | | | | | | | | | | |
| | | 17 | 118 | | | | | | | | | U | 81 | 163/10" |
| +40 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | U | 77 | 125/7" |
| +30 | | | | | | | | | | | | | | |
| | | 15 | | | | | | | | | | U | 86 | 139/7" |
| +20 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | U | 100 | 106/8" |
| +10 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | U | 44 | 70 |
| 0 | | | | | | | | | | | | GRAB | | |
| -10 | | | | | | | | | | | | | | |

ELEVATION +120'



3" ASPHALT PAVEMENT OVER GRAY SANDY GRAVEL

BROWN FINE SAND

DARK BROWN SLIGHTLY SILTY FINE SAND WITH TRACE RUBBLE, ORGANIC DEBRIS (DRY)

BROWN FINE SAND (MEDIUM DENSE)(DUNE SAND)
(GRADING SLIGHTLY MOIST AT EL. +110)

(WATER LEVEL 2/15/78, 8/22/78)

(GRADING DENSE)

(GRADING VERY DENSE)

(FEW THIN SILTY LENSES)

(OCCASIONAL THIN SILTY LENSE)

GREENISH BLACK CLAYEY SILT WITH TRACE OF DECAYED ORGANIC MATTER (VERY STIFF-HARD)

DARK GRAY FINE SAND (VERY DENSE)
(COLMA FORMATION?)

(GRADING WITH OCCASIONAL THIN STRINGER OF GRAY CLAYEY SILT)

DARK OLIVE GREEN AND BROWN-BLACK SERPENTINE HIGHLY WEATHERED AND FRACTURED
(DRILLING HARDER AT EL. +2)

NOTES:

1. SAMPLING RESISTANCE:
   SPT DRIVEN BY 140# HAMMER FALLING 30"
   U AND TW ABOVE EL. +82 DRIVEN BY 140# HAMMER FALLING 30"
   U AND TW BELOW EL. +82 DRIVEN BY 275# SLIPJARS FALLING 30"
2. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED ON OFFICIAL CITY GRADE

# LOG OF BORING

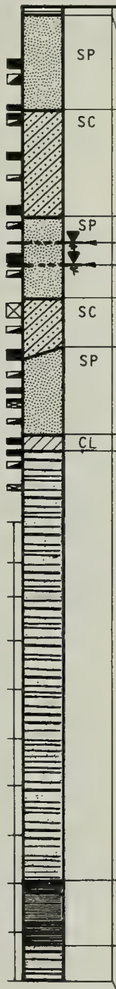
**DAMES & MOORE**

PLATE A-1A

# BORING 2

DRILLED 12/5,12,27-30/77

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | SHEAR STRENGTH TEST RESULTS, LABORATORY: TYPE OF TEST | LABORATORY: NORMAL OR CONFINING PRESSURE (PSF) | LABORATORY: PEAK SHEAR STRENGTH (PSF) | FIELD: TORVANE (PSF) | FIELD: PENETROMETER (PSF) | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT) or (HYD. PRESS., PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| +60 | | | | | | | | | | | | | | |
| | | 5 | 102 | | | | | | | | | TW | 100 | 47 |
| | | | | | | | | | | | | SPT | 100 | 24 |
| +50 | | 5 | 111 | | | | | | | | | | | |
| | SA (43%) | 11 | 129 | | | | | | | | | TW | 100 | 37 |
| | | 11 | - | | | | | | | | | SPT | 100 | 17 |
| | | 14 | 120 | | | | | | | | | TW | 50 | 26 |
| | | | | | | | | | | | | SPT | 33 | 26 |
| +40 | SA (41%) | 11 | 124 | | | | | | | | | | | |
| | | 12 | - | | | | | | | | | TW | 67 | 84 |
| | | | | | | | | | | | | SPT | 33 | 80 |
| | | 16 | 107 | | | DS/CD | 2000 | 1860 | | | | TW | 67 | 110 |
| | | 17 | - | | | | | | | | | SPT | 67 | 100/9" |
| +30 | | 35 | | | | | | | | | | | | |
| | | 22 | | | | | | | | | | TW | 75 | 20 |
| | | | | | | | | | | | | SPT | 33 | 9 |
| | SA (15%) | 22 | 104 | | | DS/CD | 2700 | 2700 | | | | TW | 78 | 105 |
| | | | | | | | | | | | | SPT | 33 | 53 |
| +20 | | 30 | 101 | | | | | | | | | TW | 100 | 50/3" |
| | | 27 | 101 | | | | | | | | | U | 100 | 212 |
| | | 23 | 102 | | | | | | | | | SPT | 100 | 86 |
| | | 21 | 106 | | | UC | | 2860 | | | | TW | 100 | 55 |
| | | | | | | | | | | | | SPT | 94 | 123/11" |
| +10 | | 14 | | | | | | | | | | TW | 40 | 150/5" |
| | | | | | | | | | | | 13 | NX | 55 | |
| | | | | | | | | | | | 7 | NX | 89 | |
| 0 | | | | | | | | | | | | | | |
| | | | | | | | | | | | 11 | NX | 100 | |
| | | | | | | | | | | | 22 | NX | 100 | |
| -10 | | | | | | | | | | | | | | |
| | | | | | | | | | | | 9 | NX | 100 | |
| | | | | | | | | | | | 6<br>23 | NX | 100 | |
| -20 | | | | | | | | | | | 7 | | | |
| | | | | | | | | | | | 14 | NX | 100 | |
| | | | | | | | | | | | 5 | NX | 100 | |
| -30 | | | | | | | | | | | | | | |
| | | | | | | | | | | | 8 | NX | 60 | |
| | | | | | | | | | | | 9 | NX | 94 | |
| | | | | | | | | | | | 17 | | | |
| -40 | | | | | | | | | | | | | | |



ELEVATION +60'

5" OF ASPHALT CONCRETE

4" OF GRAVEL BASE COURSE

SP GRAY BROWN FINE SAND (MEDIUM DENSE)(DUNE SAND)

SC DARK BROWN CLAYEY FINE SAND (MEDIUM DENSE)
(COLMA FORMATION)
(GRADING LESS CLAYEY)

(GRADING DENSE)

SP YELLOW BROWN FINE SAND (VERY DENSE)
(WATER LEVEL 2/15/78)
(WATER LEVEL 8/22/78)

SC GRAY-BROWN CLAYEY SAND WITH ORANGE MOTTLING
(MEDIUM STIFF)

SP BROWN FINE SAND WITH TRACE OF CLAY (VERY DENSE)
(GRADING LESS CLAY)

CL BROWN SILTY CLAY (VERY STIFF TO HARD)

BROWN GRAYWACKE, HIGHLY WEATHERED AND FRACTURED

BECOMING GRAY TO DARK GRAY MODERATELY WEATHERED, STRONG AND HIGHLY FRACTURED WITH STEEPLY DIPPING JOINTS, SOME CLAY FILLED
(BECOMING FRESH, VERY STRONG AND MORE MASSIVE)

(SHALE PARTINGS AT ELEV. -16.5)
(SHEAR ZONE AT ELEV. -16 TO -17')

DARK GRAY TO BLACK SHALE, FRESH, WEAK, BRECCIATED

DARK GRAY GRAYWACKE WITH OCCASIONAL SHALE PARTINGS, SLIGHTLY WEATHERED, MODERATELY FRACTURED, STRONG EXCEPT FOR SHALE PARTINGS

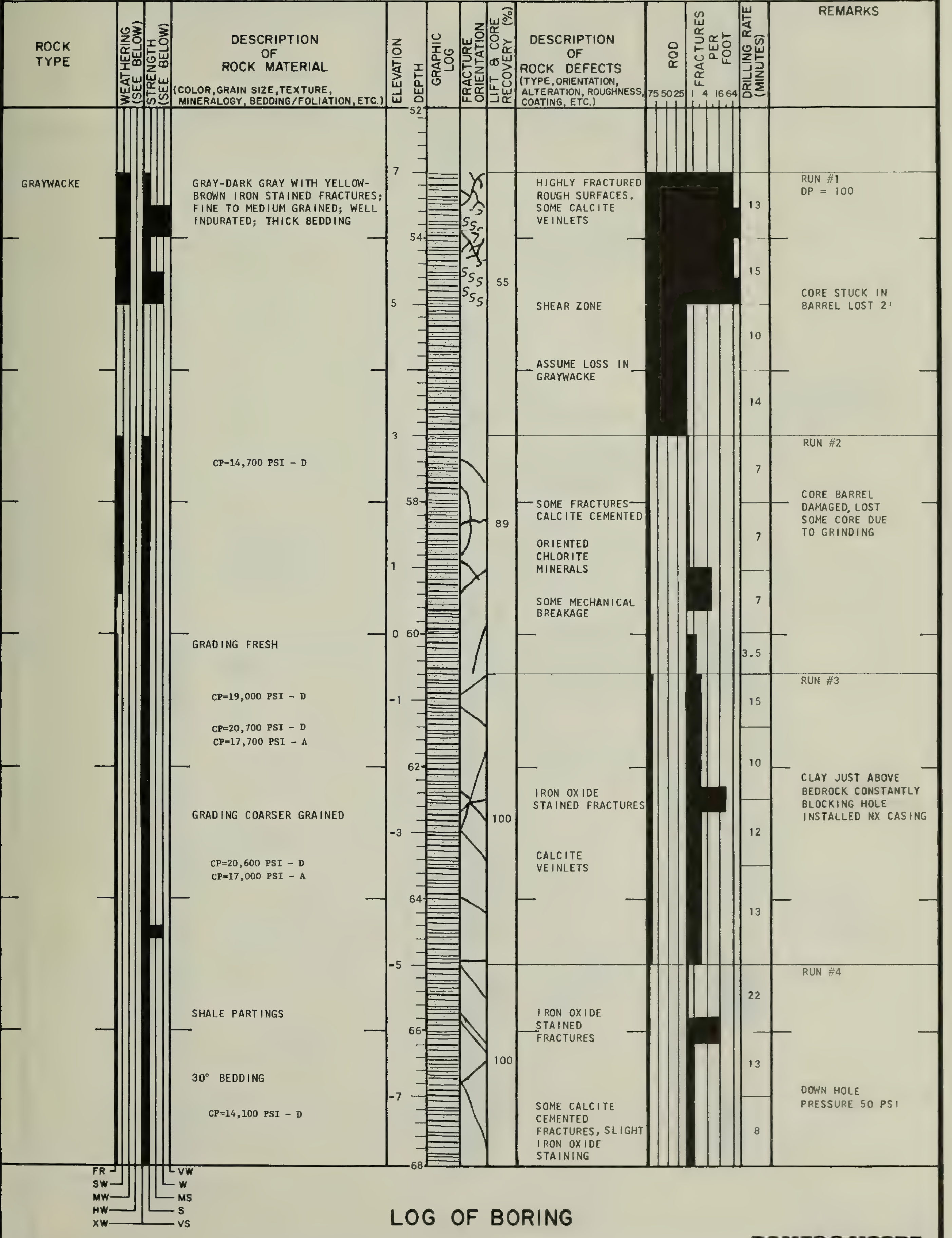
NOTES:

1. SAMPLING RESISTANCE:
   SPT DRIVEN WITH 140# HAMMER FALLING 30"
   U AND TW DRIVEN WITH 140# HAMMER FALLING 40" EXCEPT BETWEEN ELEVATIONS +47 AND +23 WHERE 320# SLIPJARS FALLING 14" WERE USED.
2. ELEVATIONS REFER TO SF DATUM AND ARE BASED ON NEARBY SURVEYED BENCHMARK
3. REFER TO FOLLOWING GEOLOGIC LOGS FOR A MORE DETAILED DESCRIPTION OF THE BEDROCK.

# LOG OF BORING

**DAMES & MOORE**

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 2
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH WITH REVERT SLURRY
LOCATION SEACLIFF NEAR 26th AVE.
ELEV. 60
PAGE 1 OF 3



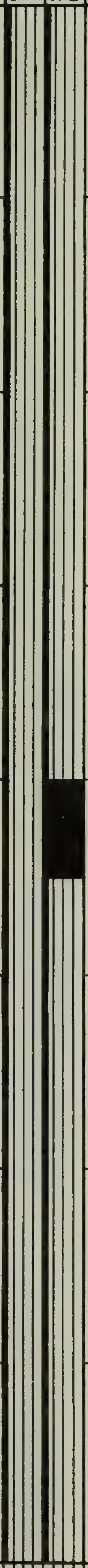
| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| | | | 52 | | | | |
| GRAYWACKE | GRAY-DARK GRAY WITH YELLOW-BROWN IRON STAINED FRACTURES; FINE TO MEDIUM GRAINED; WELL INDURATED; THICK BEDDING | 7 | | | HIGHLY FRACTURED ROUGH SURFACES, SOME CALCITE VEINLETS | 13 | RUN #1<br>DP = 100 |
| | | | 54 | | | | |
| | | | | 55 | | 15 | |
| | | 5 | | | SHEAR ZONE | | CORE STUCK IN BARREL LOST 2' |
| | | | | | | 10 | |
| | | | | | ASSUME LOSS IN GRAYWACKE | | |
| | | | | | | 14 | |
| | | 3 | | | | | RUN #2 |
| | CP=14,700 PSI - D | | | | | 7 | |
| | | | 58 | | SOME FRACTURES CALCITE CEMENTED | | CORE BARREL DAMAGED, LOST SOME CORE DUE TO GRINDING |
| | | | | 89 | ORIENTED CHLORITE MINERALS | 7 | |
| | | 1 | | | | | |
| | | | | | SOME MECHANICAL BREAKAGE | 7 | |
| | GRADING FRESH | 0 | 60 | | | | |
| | | | | | | 3.5 | |
| | | | | | | | RUN #3 |
| | CP=19,000 PSI - D | -1 | | | | 15 | |
| | CP=20,700 PSI - D<br>CP=17,700 PSI - A | | | | | | |
| | | | 62 | | | 10 | CLAY JUST ABOVE BEDROCK CONSTANTLY BLOCKING HOLE INSTALLED NX CASING |
| | GRADING COARSER GRAINED | | | 100 | IRON OXIDE STAINED FRACTURES | | |
| | | -3 | | | | 12 | |
| | CP=20,600 PSI - D<br>CP=17,000 PSI - A | | | | CALCITE VEINLETS | | |
| | | | 64 | | | 13 | |
| | | -5 | | | | | RUN #4 |
| | SHALE PARTINGS | | | | | 22 | |
| | | | 66 | | IRON OXIDE STAINED FRACTURES | | |
| | 30° BEDDING | | | 100 | | 13 | |
| | | -7 | | | | | DOWN HOLE PRESSURE 50 PSI |
| | CP=14,100 PSI - D | | | | SOME CALCITE CEMENTED FRACTURES, SLIGHT IRON OXIDE STAINING | 8 | |
| | | | 68 | | | | |

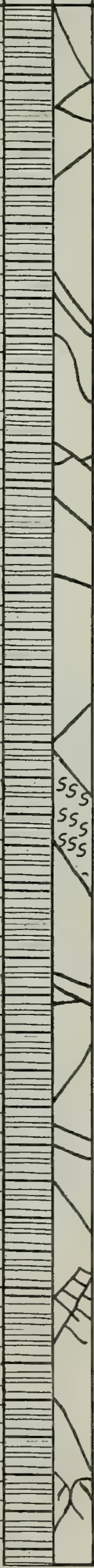
## LOG OF BORING

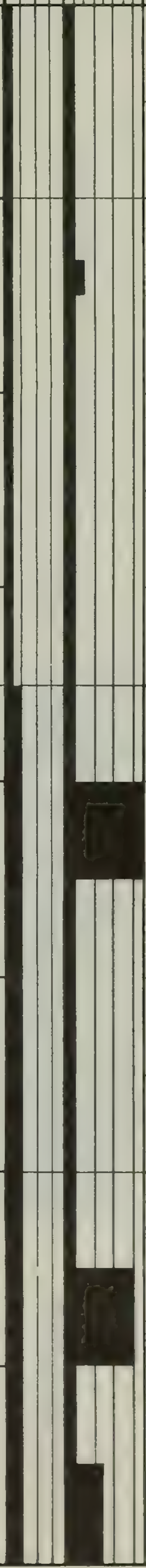
DAMES & MOORE

PLATE A-1B/1

| | | | |
|---|---|---|---|
| CLIENT: | CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03) | BORING NO. | 2 |
| PROJECT: | RICHMOND TRANSPORT SEWER | ANGLE FROM HORIZONTAL | 90° |
| DRILLING METHOD: | ROTARY WASH WITH REVERT SLURRY | | |
| LOCATION | SEACLIFF NEAR 26th. AVE. ELEV. 60 | PAGE 2 | OF 3 |







| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| GRAYWACKE | | | 68 | 100 | BREAKS ON CALCITE CEMENTED FRACTURES | 9 | RUN #4(CONT) |
| | SLIGHT BEDDING 5-10° DIP, ORIENTED CHLORITE MINERALS | -9 | | | | 12 | |
| | CP=16,700 PSI - D | | 70 | | PYRITE CRYSTALS ON FRACTURES VERY FRESH | 9 | RUN #5 |
| | | -11 | | | | 9 | |
| | | | 72 | 100 | CROSS CUTTING RELATIONSHIPS OF CALCITE VEINLETS EXHIBITS SEVERAL PHASE OF DEFORMATION | 10 | LESS ALTERATION WITH DEPTH FRACTURES, MORE CEMENTED (CALCITE) |
| | | -13 | | | | 9 | |
| | CP=24,600 PSI - D<br>CP=24,700 PSI - D<br>CP=21,200 PSI - D<br>CP=28,600 PSI - D | | 74 | | | 8 | |
| | | -15 | | | | 7 | RUN #6 |
| | GRAYWACKE WITH SHALE PARTINGS | | 76 | 100 | SHEAR ZONE<br>SHALE PARTINGS AND BRECCIATION | 4 | |
| | | -17 | | | | 9 | |
| | | | 78 | | | 23 | DOWN HOLE PRESSURE=100 PSI |
| | | -19 | | | | 7 | |
| | | | 80 | | | 6 | RUN #7<br>DOWN HOLE PRESSURE=50 PSI |
| | | -21 | | | SOME MECHANICAL BREAKAGE ON CALCITE CEMENTED FRACTURES | 7 | |
| | CP=25,000 PSI - D<br>CP=13,100 PSI - A | | 82 | 100 | | 7 | |
| | | -23 | | | | 14 | DOWN HOLE PRESSURE 100 PSI |
| | | | 84 | | | | |

RQD: 75 50 25

FRACTURES PER FOOT: 1 4 16 64

WEATHERING (SEE BELOW): FR, SW, MW, HW, XW

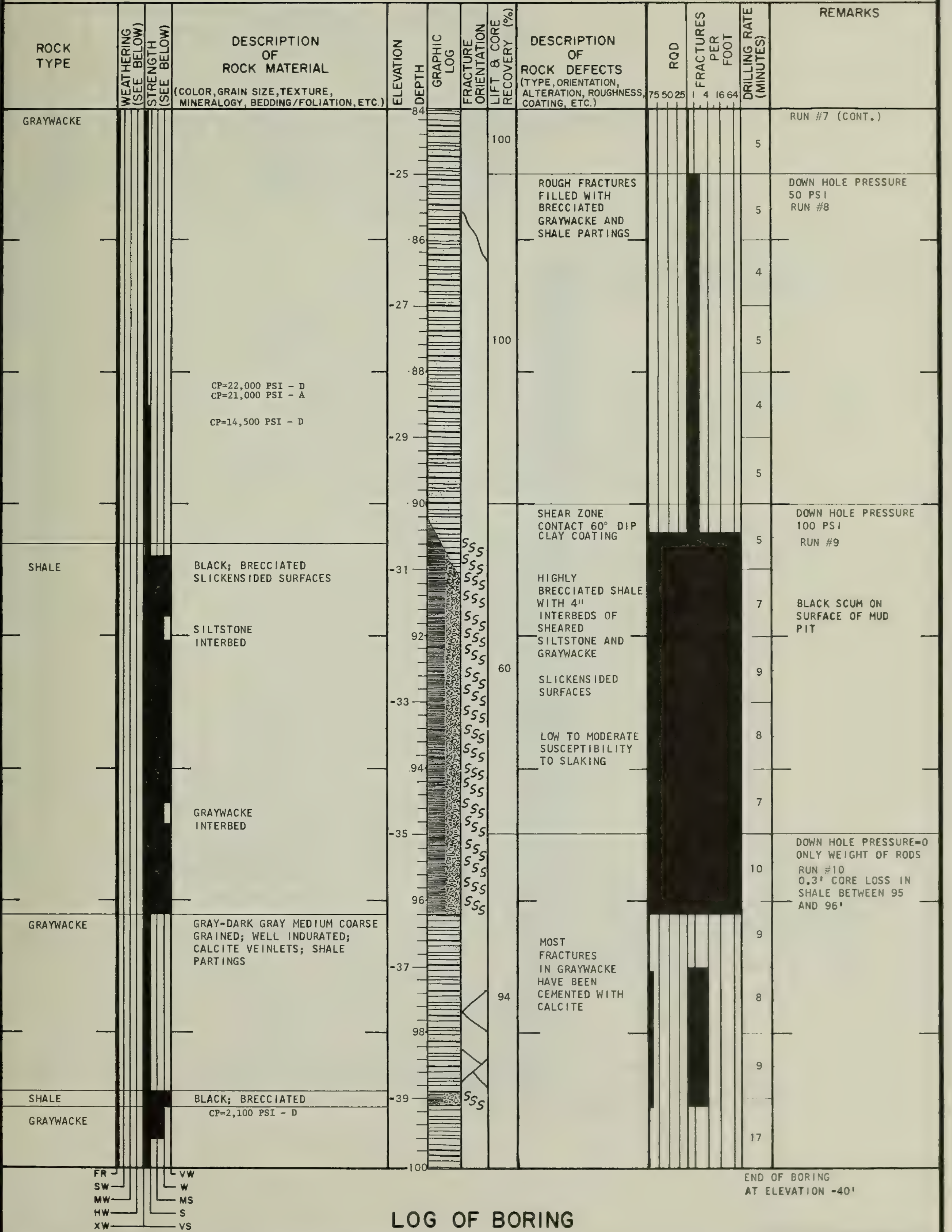
STRENGTH (SEE BELOW): VW, W, MS, S, VS

## LOG OF BORING

**DAMES & MOORE**

PLATE A-1B/2

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 2
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH WITH REVERT SLURRY
LOCATION SEACLIFF NEAR 26th. AVE.
ELEV. 60
PAGE 3 OF 3



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| GRAYWACKE | | | 84 | 100 | | 5 | RUN #7 (CONT.) |
| | | -25 | | | ROUGH FRACTURES FILLED WITH BRECCIATED GRAYWACKE AND SHALE PARTINGS | 5 | DOWN HOLE PRESSURE 50 PSI<br>RUN #8 |
| | | | 86 | | | 4 | |
| | | -27 | | 100 | | 5 | |
| | CP=22,000 PSI - D<br>CP=21,000 PSI - A<br>CP=14,500 PSI - D | | 88 | | | 4 | |
| | | -29 | | | | 5 | |
| SHALE | BLACK; BRECCIATED SLICKENSIDED SURFACES | | 90 | | SHEAR ZONE CONTACT 60° DIP CLAY COATING | 5 | DOWN HOLE PRESSURE 100 PSI<br>RUN #9 |
| | SILTSTONE INTERBED | -31 | | | HIGHLY BRECCIATED SHALE WITH 4" INTERBEDS OF SHEARED SILTSTONE AND GRAYWACKE | 7 | BLACK SCUM ON SURFACE OF MUD PIT |
| | | | 92 | 60 | SLICKENSIDED SURFACES | 9 | |
| | | -33 | | | LOW TO MODERATE SUSCEPTIBILITY TO SLAKING | 8 | |
| | GRAYWACKE INTERBED | | 94 | | | 7 | |
| | | -35 | | | | 10 | DOWN HOLE PRESSURE=0 ONLY WEIGHT OF RODS<br>RUN #10<br>0.3' CORE LOSS IN SHALE BETWEEN 95 AND 96' |
| GRAYWACKE | GRAY-DARK GRAY MEDIUM COARSE GRAINED; WELL INDURATED; CALCITE VEINLETS; SHALE PARTINGS | | 96 | | MOST FRACTURES IN GRAYWACKE HAVE BEEN CEMENTED WITH CALCITE | 9 | |
| | | -37 | | 94 | | 8 | |
| | | | 98 | | | 9 | |
| SHALE<br>GRAYWACKE | BLACK; BRECCIATED<br>CP=2,100 PSI - D | -39 | | | | 17 | |
| | | | 100 | | | | END OF BORING AT ELEVATION -40' |

## LOG OF BORING

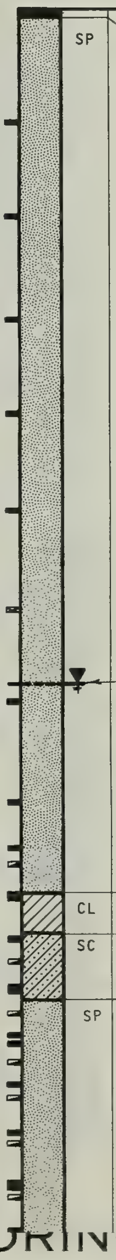
**DAMES & MOORE**

PLATE A-1B/3

# LOG OF BORING

## BORING 3
DRILLED 12/7-9/77

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | SHEAR STRENGTH TEST RESULTS, LABORATORY: TYPE OF TEST | LABORATORY: NORMAL OR CONFINING PRESSURE (PSF) | LABORATORY: PEAK SHEAR STRENGTH (PSF) | FIELD: TORVANE (PSF) | FIELD: PENETROMETER (PSF) | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD.PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| +150 | | | | | | | | | | | | | | |
| +140 | | | | | | | | | | | | | | |
| +130 | | 14 | 111 | | | | | | | | | U | 78 | 17 |
| +120 | | 13 | 105 | | | | | | | | | U | 78 | 24 |
| +110 | | 18 | 101 | | | | | | | | | U | 93 | 106/9" |
| +100 | | 14 | 112 | | | | | | | | | U | | 95 |
| +90 | | 14 | 114 | | | | | | | | | U | 78 | 103 |
| +80 | | 16 | | | | | | | | | | U | 78 | 74 |
| +70 | | 17 | 109 | | | | | | | | | U | 93 | 110/9" |
| +60 | | 19 | 107 | | | | | | | | | U | 67 | 103 |
| | | 19 | 114 | | | DS/CD | 8800 | 6120 | | | | TW | | 78 |
| | | | | | | | | | | | | SPT | 67 | 50 |
| +50 | | 18 | 110 | | | DS/CD | 9000 | 6900 | | | | TW | 72 | 28 |
| | | 22 | 103 | 23 | 16 | DS/CD | 9000 | 4980 | | | | | | |
| | | 14 | 119 | | | DS/CD | 9300 | 7080 | | | | TW | 78 | 33 |
| | | | | | | | | | | | | SPT | 100 | 32 |
| | | 15 | 117 | | | DS/CD | 9500 | 6720 | | | | TW | 78 | 19 |
| +40 | | | | | | | | | | | | SPT | 100 | 84 |
| | | 16 | 112 | | | DS/CD | 9800 | 7680 | | | | TW | 78 | 64 |
| | | | | | | | | | | | | SPT | 100 | 108/9" |
| | | 18 | 116 | | | | | | | | | U | 100 | 61/6" |
| +30 | | | | | | | | | | | | SPT | 100 | 90/5" |
| | | 17 | 111 | | | DS/CD | 10,300 | 10,200 | | | | TW | 91 | 90/5" |
| | | | | | | | | | | | | SPT | 100 | 50/2" |
| | PERM<br>SA<br>(17%) | 17 | 116 | | | | | | | | | TW | 78 | 72 |
| +20 | | | | | | | | | | | | SPT | 100 | 60/6" |



ELEVATION +142'

ASPHALT AND CONCRETE 7" THICK

SP BROWN FINE SAND (MEDIUM DENSE)(DUNE SAND)

(GRADING LIGHT BROWN, SLIGHTLY MORE DENSE)

(GRADING VERY DENSE)

(BECOMING GRAY-BROWN)

(WATER LEVEL 2/15/78, 8/22/78)

(GRADING WITH TRACE OF SILT)

CL BLACK FINE SANDY SILTY CLAY, (STIFF)(COLMA FM)

SC LIGHT GRAY-BROWN SILTY CLAYEY FINE SAND WITH IRON OXIDE AND BLACK MOTTLING (MEDIUM DENSE TO DENSE) (GRADING MORE CLAYEY AT EL.+45)

SP BROWN SLIGHTLY SILTY FINE SAND,
(GRADING TO TRACE OF SILT WITH IRON OXIDE STAINING)
(GRADING DENSER, THIN GRAVELLY LAYER)

(THIN GRAVELLY LAYER)

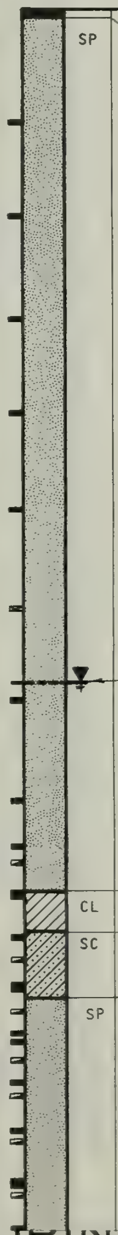
(GRADING SLIGHTLY SILTIER)

(PARTIAL IRON OXIDE CEMENTATION)

## BORING 3

DRILLED 12/7-9/77

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | SHEAR STRENGTH TEST RESULTS, LABORATORY: TYPE OF TEST | LABORATORY: NORMAL OR CONFINING PRESSURE (PSF) | LABORATORY: PEAK SHEAR STRENGTH (PSF) | FIELD: TORVANE (PSF) | FIELD: PENETROMETER (PSF) | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT) or (HYD. PRESS., PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| +150 | | | | | | | | | | | | | | |
| +140 | | | | | | | | | | | | | | |
| +130 | | 14 | 111 | | | | | | | | | U | 78 | 17 |
| +120 | | 13 | 105 | | | | | | | | | U | 78 | 24 |
| +110 | | 18 | 101 | | | | | | | | | U | 93 | 106/9" |
| +100 | | 14 | 112 | | | | | | | | | U | | 95 |
| +90 | | 14 | 114 | | | | | | | | | U | 78 | 103 |
| +80 | | 16 | | | | | | | | | | U | 78 | 74 |
| +70 | | 17 | 109 | | | | | | | | | U | 93 | 110/9" |
| +60 | | 19 | 107 | | | | | | | | | U | 67 | 103 |
| | | 19 | 114 | | | DS/CD | 8800 | 6120 | | | | TW | | 78 |
| | | | | | | | | | | | | SPT | 67 | 50 |
| | | 18 | 110 | | | DS/CD | 9000 | 6900 | | | | TW | 72 | 28 |
| +50 | | 22 | 103 | 23 | 16 | DS/CD | 9000 | 4980 | | | | | | |
| | | 14 | 119 | | | DS/CD | 9300 | 7080 | | | | TW | 78 | 33 |
| | | | | | | | | | | | | SPT | 100 | 32 |
| | | 15 | 117 | | | DS/CD | 9500 | 6720 | | | | TW | 78 | 19 |
| +40 | | | | | | | | | | | | SPT | 100 | 84 |
| | | 16 | 112 | | | DS/CD | 9800 | 7680 | | | | TW | 78 | 64 |
| | | | | | | | | | | | | SPT | 100 | 108/9" |
| | | 18 | 116 | | | | | | | | | U | 100 | 61/6" |
| +30 | | | | | | | | | | | | SPT | 100 | 90/5" |
| | | 17 | 111 | | | DS/CD | 10,300 | 10,200 | | | | TW | 91 | 90/5" |
| | | | | | | | | | | | | SPT | 100 | 50/2" |
| +20 | PERM<br>SA<br>(17%) | 17 | 116 | | | | | | | | | TW | 78 | 72 |
| | | | | | | | | | | | | SPT | 100 | 60/6" |



ELEVATION +142'

ASPHALT AND CONCRETE 7" THICK

SP BROWN FINE SAND (MEDIUM DENSE) (DUNE SAND)

(GRADING LIGHT BROWN, SLIGHTLY MORE DENSE)

(GRADING VERY DENSE)

(BECOMING GRAY-BROWN)

(WATER LEVEL 2/15/78, 8/22/78)

(GRADING WITH TRACE OF SILT)

CL BLACK FINE SANDY SILTY CLAY. (STIFF) (COLMA FM)

SC LIGHT GRAY-BROWN SILTY CLAYEY FINE SAND WITH IRON OXIDE AND BLACK MOTTLING (MEDIUM DENSE TO DENSE) (GRADING MORE CLAYEY AT EL.+45)

SP BROWN SLIGHTLY SILTY FINE SAND.
(GRADING TO TRACE OF SILT WITH IRON OXIDE STAINING)
(GRADING DENSER, THIN GRAVELLY LAYER)
(THIN GRAVELLY LAYER)
(GRADING SLIGHTLY SILTIER)
(PARTIAL IRON OXIDE CEMENTATION)

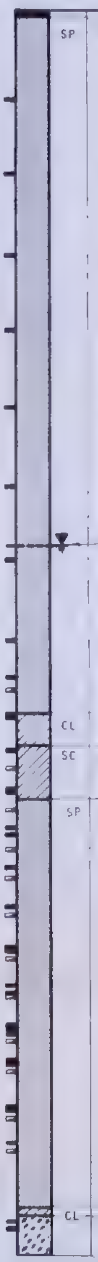
# LOG OF BORING

**DAMES & MOORE**

# BORING 3

DRILLED 12/7-9/77

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS<br>LIQUID LIMIT | ATTERBERG LIMITS<br>PLASTIC LIMIT | SHEAR STRENGTH TEST RESULTS, LABORATORY<br>TYPE OF TEST | SHEAR STRENGTH TEST RESULTS, LABORATORY<br>NORMAL CONFINING PRESSURE (PSF) | SHEAR STRENGTH TEST RESULTS, LABORATORY<br>PEAK SHEAR STRENGTH (PSF) | SHEAR STRENGTH TEST RESULTS, FIELD<br>TORVANE (PSF) | SHEAR STRENGTH TEST RESULTS, FIELD<br>PENETROMETER (PSF) | CORING RATE (MIN/FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)(or HYD PRESS,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| +150 | | | | | | | | | | | | | | |
| +140 | | | | | | | | | | | | | | |
| +130 | | 14 | 111 | | | | | | | | | U | 78 | 17 |
| +120 | | 13 | 105 | | | | | | | | | U | 78 | 24 |
| +110 | | 18 | 101 | | | | | | | | | U | 93 | 106/9 |
| +100 | | 14 | 112 | | | | | | | | | U | | 95 |
| +90 | | 14 | 114 | | | | | | | | | U | 78 | 103 |
| +80 | | 16 | | | | | | | | | | U | 78 | 74 |
| +70 | | 17 | 109 | | | | | | | | | U | 93 | 110/9' |
| +60 | | 19 | 107 | | | | | | | | | | 67 | 103 |
| | | 19 | 114 | | | DS/CD | 8800 | 6120 | | | | TW<br>SPT | <br>67 | 78<br>50 |
| +50 | | 18 | 110 | | | DS/CD | 9000 | 6900 | | | | TW | 72 | 28 |
| | | 22 | 103 | 23 | 16 | DS CD | 9000 | 4980 | | | | | | |
| | | 14 | 119 | | | DS/CD | 9300 | 7080 | | | | TW<br>SPT | 78<br>100 | 33<br>32 |
| +40 | | 15 | 117 | | | DS/CD | 9500 | 6720 | | | | TW<br>SPT | 78<br>100 | 19<br>84 |
| | | 16 | 112 | | | DS/CD | 9800 | 7680 | | | | TW<br>SPT | 78<br>100 | 64<br>108/9" |
| +30 | | 18 | 116 | | | | | | | | | U<br>SPT | 100<br>100 | 61/6"<br>90/5" |
| | | 17 | 111 | | | DS/CD | 10,300 | 10,200 | | | | TW<br>SPT | 91<br>100 | 90/5<br>50/2 |
| +20 | PERM SA (7..) | 17 | 116 | | | | | | | | | TW<br>SPT | 78<br>100 | 72<br>60/6" |
| | | 22 | 104 | | | DS/CD | 10,800 | 7290 | | | | TW<br>SPT | 97<br>100 | 85<br>50/1" |
| +10 | | 21 | 108 | | | | | | | | | TW | 100 | 83/11" |
| | | | | | | | | | | | | SPT | 92 | 91/6" |
| | | 12 | 113 | | | DS/CD | 11,300 | 10,020 | | | | TW<br>SPT | 83<br>89 | 64/6"<br>50/3" |
| 0 | | 22 | 106 | | | | | | | | | TW<br>SPT | 89<br>82 | 95<br>50/5" |
| | | | | | | | | | | | | TW<br>SPT | 71<br>100 | 85/8"<br>100/5' |
| -10 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | U | 94 | 11 |
| -20 | | | | | | | | | | | | | | |



ELEVATION +142'

ASPHALT AND CONCRETE 7" THICK

SP BROWN FINE SAND (MEDIUM DENSE) (DUNE SAND)

(GRADING LIGHT BROWN, SLIGHTLY MORE DENSE)

(GRADING VERY DENSE

(BECOMING GRAY-BROWN)

(WATER LEVEL 2/15/78, 8/22/78)

(GRADING WITH TRACE OF SILT)

CL BLACK FINE SANDY SILTY CLAY, (STIFF) (COLMA FM)

SC LIGHT GRAY-BROWN SILT CLAYEY FINE SAND WITH IRON OXIDE AND BLACK MOTTLING (MEDIUM DENSE TO DENSE) (GRADING MORE CLAYEY AT EL.+45)

SP BROWN SLIGHTLY SILTY FINE SAND,
(GRADING TO TRACE OF SILT WITH IRON OXIDE STAINING)
(GRADING DENSER, THIN GRAVELLY LAYER)

(THIN GRAVELLY LAYER

(GRADING SLIGHTLY SILTIER)

(PARTIAL IRON OXIDE CEMENTATION)

(IRON OXIDE CEMENTATION, GRADING OUT)
(GRADING DARK BROWN, TRACE OF SILT)

(GRADING BROWN WITHOUT SILT AND WITH SOME IRON OXIDE STAINING)
(GRADING SLIGHTLY SILTY)

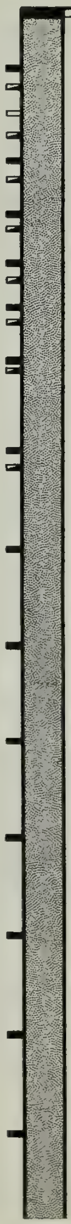
CL YELLOW-BROWN SILTY CLAY (WEATHERED BEDROCK)
YELLOW-GREEN AND BLACK HIGHLY WEATHERED AND ALTERED SERPENTINE ROCK
BECOMING HARDER AT EL. -15.5'

NOTES:
1. SAMPLING RESISTANCE:
SPT DRIVEN BY 140# HAMMER FALLING 30"
U AND TW DRIVEN BY 275# SLIPJARS FALLING 30"
2. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED ON OFFICIAL CITY GRADE

# LOG OF BORING

## BORING 4
DRILLED 12/12-13/77

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | SHEAR STRENGTH TEST RESULTS, LABORATORY: TYPE OF TEST | SHEAR STRENGTH TEST RESULTS, LABORATORY: NORMAL OR CONFINING PRESSURE (PSF) | SHEAR STRENGTH TEST RESULTS, LABORATORY: PEAK SHEAR STRENGTH (PSF) | SHEAR STRENGTH TEST RESULTS, FIELD: TORVANE (PSF) | SHEAR STRENGTH TEST RESULTS, FIELD: PENETROMETER (PSF) | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD. PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| +120 | | | | | | | | | | | | | | |
| +110 | | 13 | 105 | | | | | | | | | TW<br>SPT<br>TW<br>SPT | 78<br>75<br>00<br>67 | 20<br>38/10"<br>17<br>42 |
| +100 | | 12 | 108 | | | DS/CD | 1700 | 1524 | | | | TW<br>SPT<br>TW<br>SPT | 78<br>67<br>67<br>67 | 22<br>46<br>31<br>64 |
| +90 | | 13 | 107 | | | DS/CD | 2700 | 1992 | | | | TW<br>SPT<br>TW<br>SPT | 78<br>75<br>50<br>67 | 43<br>115/10"<br>51<br>100/6" |
| +80 | | 17 | 110 | | | DS/CD | 4000 | 2880 | | | | TW<br>SPT | 61<br>100 | 61<br>50/6" |
| +70 | | 19 | 103 | | | | | | | | | TW<br>SPT | 67<br>100 | 83<br>50/3" |
| +60 | | 15 | 117 | | | DS/CD | 5700 | 3720 | | | | U | 83 | 50/6" |
| +50 | | 18 | 118 | | | | | | | | | U | 55 | 50/5" |
| +40 | | | | | | | | | | | | U | 52 | 50/5.5" |
| +30 | | 21 | 108 | | | | | | | | | U | 78 | 87 |
| +20 | | | | | | | | | | | | U | 85 | 90/11" |
| +10 | | | | | | | | | | | | U | 88 | 97/10" |
| 0 | | | | | | | | | | | | U | 82 | 89/11" |
| -10 | | | | | | | | | | | | | | |



ELEVATION +114'

ASPHALT PAVEMENT

SP GRAY-BROWN FINE SAND (MEDIUM DENSE)(DUNE SAND)

(GRADING DENSE)

(GRADING TO VERY DENSE)

(NO GROUND WATER TO +65', HOLE CAVED)
(GROUND WATER ESTIMATED AT +65')

# LOG OF BORING

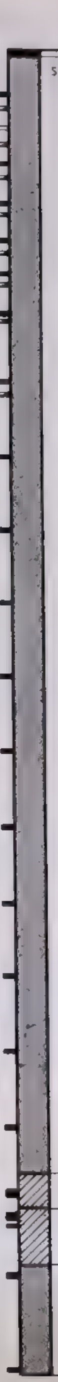
**DAMES & MOORE**

PLATE A-1D

## BORING 4

DRILLED 12/12-13/77

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS |  | SHEAR STRENGTH TEST RESULTS |  |  |  |  | CORING RATE (MIN/FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | LABORATORY |  |  | FIELD |  |  |  |  |  |
|  |  |  |  | LIQUID LIMIT | PLASTIC LIMIT | TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | TORVANE (PSF) | PENETROMETER (PSF) |  |  |  |  |
| +120 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| +110 |  | 13 | 105 |  |  |  |  |  |  |  |  | TW | 78 | 20 |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 75 | 38/10" |
|  |  |  |  |  |  |  |  |  |  |  |  | TW | 00 | 17 |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 67 | 42 |
| +100 |  | 12 | 108 |  |  | DS/CD | 1700 | 1524 |  |  |  | TW | 78 | 22 |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 67 | 46 |
|  |  |  |  |  |  |  |  |  |  |  |  | TW | 67 | 31 |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 67 | 64 |
| +90 |  | 13 | 107 |  |  | DS/CD | 2700 | 1992 |  |  |  | TW | 78 | 43 |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 75 | 115/10" |
|  |  |  |  |  |  |  |  |  |  |  |  | TW | 50 | 51 |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 67 | 100/6" |
| +80 |  | 17 | 110 |  |  | DS/CD | 4000 | 2880 |  |  |  | TW | 61 | 61 |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 100 | 50/6" |
| +70 |  | 19 | 103 |  |  |  |  |  |  |  |  | TW | 67 | 83 |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 100 | 50/3" |
| +60 |  | 15 | 117 |  |  | DS/CD | 5700 | 3720 |  |  |  | U | 83 | 50/6" |
| +50 |  | 18 | 118 |  |  |  |  |  |  |  |  | U | 55 | 50/5" |
| +40 |  |  |  |  |  |  |  |  |  |  |  | U | 52 | 50/5.5" |
| +30 |  | 21 | 108 |  |  |  |  |  |  |  |  | U | 78 | 87 |
| +20 |  |  |  |  |  |  |  |  |  |  |  | U | 85 | 90/11" |
| +10 |  |  |  |  |  |  |  |  |  |  |  | U | 88 | 97/10" |
| 0 |  |  |  |  |  |  |  |  |  |  |  | U | 82 | 89/11" |
| -10 |  |  |  |  |  |  |  |  |  |  |  | U | 82 | 50/5" |
| -20 |  | 22 | 106 |  |  |  |  |  |  |  |  | U | 82 | 86/11" |
| -30 |  |  |  |  |  |  |  |  |  |  |  | U | 82 | 85/11" |
| -40 |  | 16 | 115 | 20 | 15 |  |  |  |  |  |  | TW | 81 | 13 |
|  |  | 18 | 111 |  |  |  |  |  |  |  |  | TW | 100 | 17 |
| -50 |  |  |  |  |  |  |  |  |  |  |  | TW | 64 | 50/5" |
| -60 |  | 17 | 115 |  |  |  |  |  |  |  |  | U | 81 | 58 |
| -70 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |



ELEVATION +114'

ASPHALT PAVEMENT

SP GRAY-BROWN FINE SAND (MEDIUM DENSE)(DUNE SAND)

(GRADING DENSE)

(GRADING TO VERY DENSE)

(NO GROUND WATER TO +65', HOLE CAVED)
(GROUND WATER ESTIMATED AT +65')

(GRADING SLIGHTLY SILTY)

(TRACE OF SILT)

SC DARK GRAY GREEN CLAYEY SAND (MEDIUM DENSE) (COLMA FORMATION)

SC YELLOW BROWN CLAYEY FINE SAND, LIMONITE STAINED (MEDIUM DENSE)

SP YELLOW BROWN FINE SAND (VERY DENSE)

(GRADING SLIGHTLY CLAYEY)

NOTES:

1. SAMPLING RESISTANCE:
   SPT DRIVEN BY 140# HAMMER FALLING 30"
   U AND TW DRIVEN BY 275# SLIPJARS FALLING 30"
2. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED ON OFFICIAL CITY GRADE

# LOG OF BORING

DAMES & MOORE

PLATE A-10

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS |  | SHEAR STRENGTH TEST RESULTS |  |  |  |  | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD.PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | LABORATORY |  |  | FIELD |  |  |  |  |  |
|  |  |  |  | LIQUID LIMIT | PLASTIC LIMIT | TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | TORVANE (PSF) | PENETROMETER (PSF) |  |  |  |  |
| +70 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| +60 |  | 1 | 105 |  |  |  |  |  |  |  |  | TW | 88 | 31 |
| +50 |  | 2 | 99 |  |  |  |  |  |  |  |  | TW | 100 | 34 |
|  |  | 2 | 101 |  |  | DS/CD | 2700 | 1600 |  |  |  | TW | 100 | 38 |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 100 | 26 |
| +40 |  |  |  |  |  |  |  |  |  |  |  | TW | 67 | 82 |
|  |  | 17 | 112 |  |  | DS/CD | 3500 | 2750 |  |  |  | SPT | 100 | 31 |
|  |  |  |  |  |  |  |  |  |  |  |  | TW | 71 | 96 |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 33 |  |
| +30 | PERM<br>SA<br>(3%) | 18 | 109 |  |  | DS/CD | 3700 | 3170 |  |  |  | U |  | 119 |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 0 |  |
| +20 |  |  |  |  |  |  |  |  |  |  |  | U | 0 | 175 |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 0 |  |
|  |  |  |  |  |  |  |  |  |  |  |  | U | 100 |  |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 72 | 97 |
| +10 |  |  |  |  |  |  |  |  |  |  |  | U | 0 | 315 |
|  |  |  |  |  |  |  |  |  |  |  |  | U | 0 | 189/11" |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 44 |  |
| 0 |  | 20 | 111 |  |  | DS/CD | 5200 | 3850 |  |  |  | TW | 75 | 95/6" |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 94 | 171 |
|  |  |  |  |  |  |  |  |  |  |  |  | U | 61 | 100/5" |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 100 | 29 |
| -10 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | 22 | 103 |  |  |  |  |  |  |  |  | U | 59 | 104/5" |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 67 |  |
|  |  | 15 | 109 |  |  |  |  |  |  |  |  | U | 78 | 84 |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 89 |  |
| -20 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | 17 | 111 |  |  |  |  |  |  |  |  | U | 56 | 93 |
| -30 |  | 19 | 109 |  |  |  |  |  |  |  |  | U | 77 | 170/7" |
| -40 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

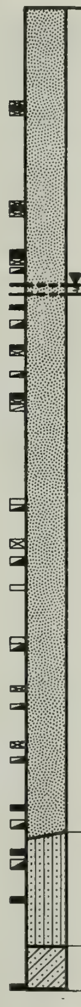
NOTES:

1. SAMPLING RESISTANCE:
   SPT, U AND TW DRIVEN BY 140# HAMMER FALLING 30"
2. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED ON
   OFFICIAL CITY GRADE

## BORING 5

DRILLED 12/12-19/77

ELEVATION +70.5'



SP — LIGHT BROWN FINE SAND, LITTLE SILT (MEDIUM DENSE)
(SILT GRADING OUT) (DUNE SAND)

(WATER LEVEL 2/15/78, 6/9/78)

(GRADING DENSE)

(GRADING TO MEDIUM DENSE)

SM — GRAY SILTY FINE TO MEDIUM SAND (VERY DENSE)
(COLMA FORMATION)

SC — GREENISH CLAYEY SILTY FINE SAND (VERY DENSE)

# LOG OF BORING

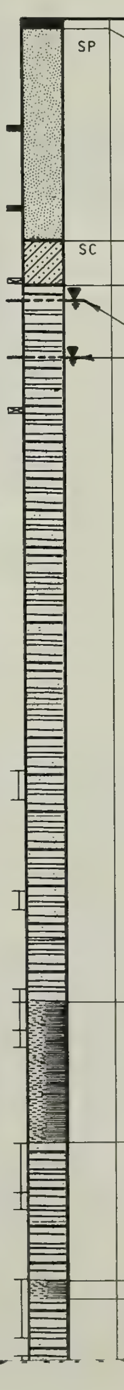
DAMES & MOORE

PLATE A-1E

# BORING 6

DRILLED 12/14-21/77

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS | | SHEAR STRENGTH TEST RESULTS | | | | | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD. PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | LABORATORY | | | FIELD | | | | | |
| | | | | LIQUID LIMIT | PLASTIC LIMIT | TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | TORVANE (PSF) | PENETROMETER (PSF) | | | | |
| +150 | | | | | | | | | | | | | | |
| +140 | | | | | | | | | | | | U | 78 | 16 |
| +130 | | | | | | | | | | | | U | 78 | 20 |
| | | | | | | | | | | | | TW | 36 | 100<br>5" |
| +120 | | | | | | | | | | | | | | |
| +110 | | | | | | | | | | | | U | 67 | 100<br>3" |
| +100 | | | | | | | | | | | | | | |
| +90 | | | | | | | | | | | | | | |
| +80 | | | | | | | | | | | | | | |
| +70 | | | | | | | | | | | 7<br>7<br>7 | NX | 83 | |
| +60 | | | | | | | | | | | 10<br>10 | NX | 100 | |
| +50 | | | | | | | | | | | | NX<br>NX<br>NX | 100<br>100<br>100 | |
| +40 | | | | | | | | | | | | | | |
| | | | | | | | | | | | 9 | NX | 50 | |
| +30 | | | | | | | | | | | | NX | 100 | |
| +20 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | NX | 91 | |



ELEVATION 150'

ASPHALT AND CONCRETE

BROWN FINE SAND, (MEDIUM DENSE) (DUNE SAND)

(GRADING WITH A TRACE OF CLAY)

YELLOW BROWN CLAYEY FINE SAND (VERY DENSE) (COLLUVIUM)

GRAY GRAYWACKE BEDROCK, HIGHLY WEATHERED AND FRACTURED

(WATER LEVEL 8/22/78)

(WATER LEVEL 2/15/78)

(STRONG, FRESH, LESS FRACTURED)

GRAY GRAYWACKE, FRESH, VERY STRONG (RQD=25%)

(RQD=45%)

(GRADING WITH SHALE PARTINGS)

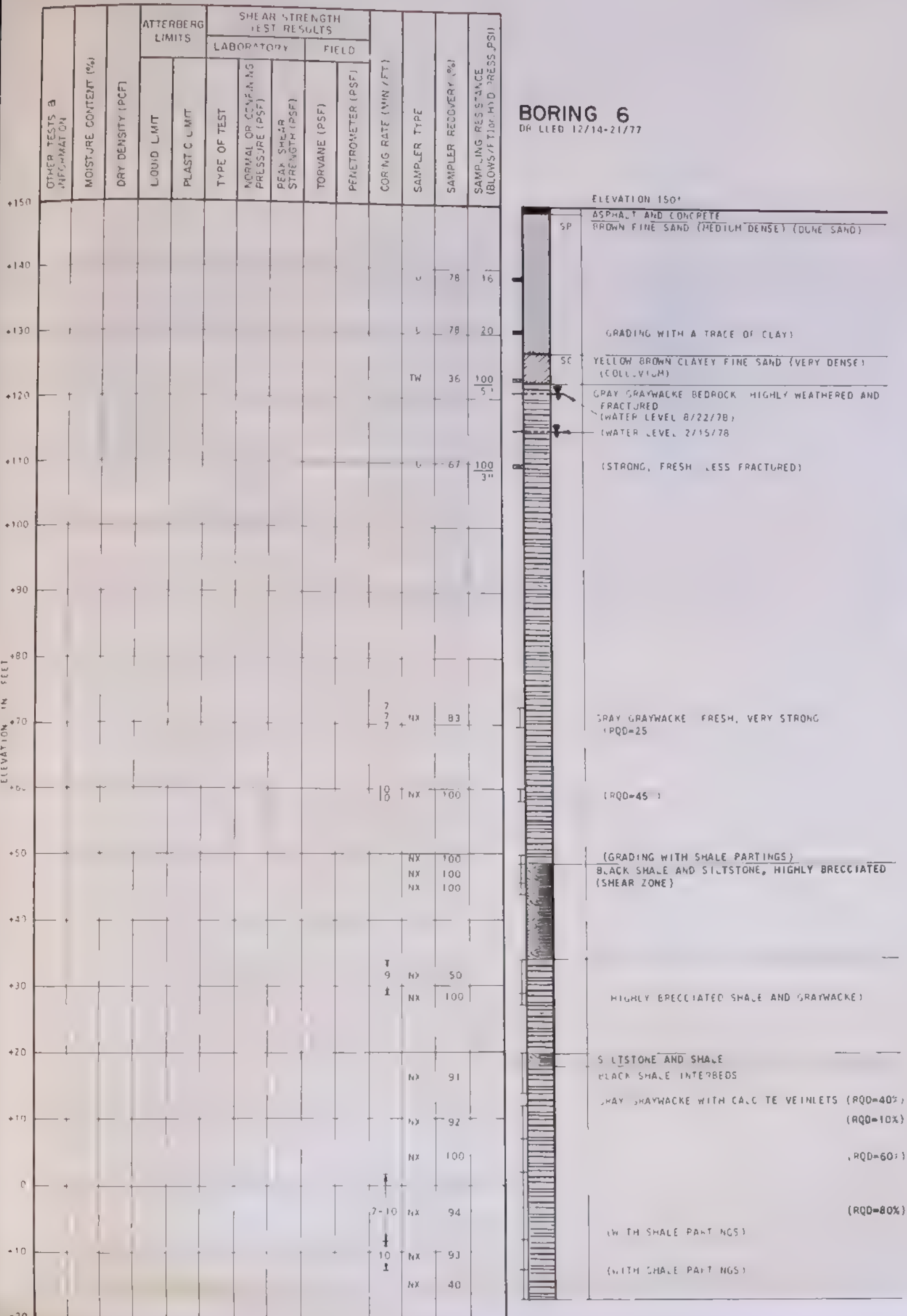
BLACK SHALE AND SILTSTONE, HIGHLY BRECCIATED (SHEAR ZONE)

(HIGHLY BRECCIATED SHALE AND GRAYWACKE)

SILTSTONE AND SHALE

BLACK SHALE INTERBEDS

GRAY GRAYWACKE WITH CALCITE VEINLETS (RQD=40%)



NOTES

1. SAMPLING RESISTANCE
   SPT DRIVEN BY 140 HAMMER FALLING 30
   U AND TW DRIVEN BY 75 SLIPJARS FALLING 30'
2. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED ON NEARBY SURVEYED BENCHMARK.
3. REFER TO FOLLOWING GEOLOGIC LOGS FOR A MORE DETAILED DESCRIPTION OF THE BEDROCK.

# LOG OF BORING

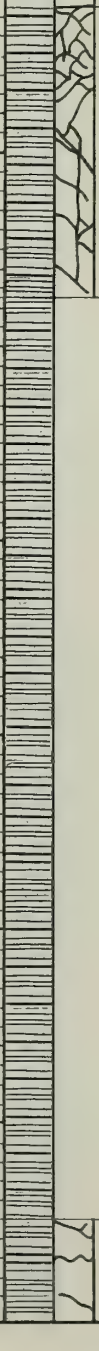
**DAMES & MOORE**

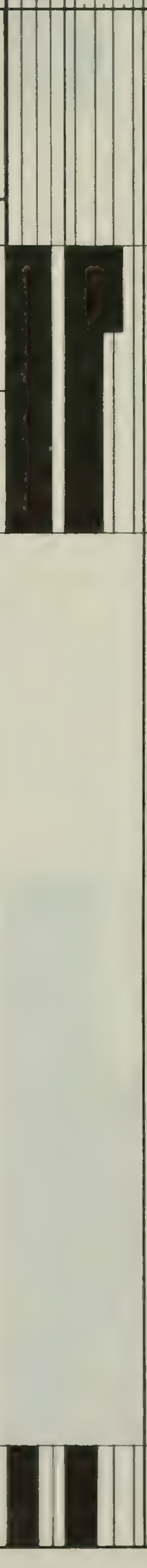
PLATE A-1F

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 6
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH WITH REVERT SLURRY
LOCATION 29th AVE. NEAR LAKE STREET
ELEV. 150
PAGE 1 OF 6

| ROCK TYPE | WEATHERING (SEE BELOW) | STRENGTH (SEE BELOW) | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| GRAYWACKE | | | GRAY; FINE TO MEDIUM GRAINED; WELL INDURATED; MASSIVE BEDDING | 83 | MOST FRACTURES COATED WITH CALCITE; SOME HAVE CLAY COATING | 22 | RUN #1<br>DRILLING HARD FRANCISCAN GRAYWACKE<br>DRILLING RATE 1' IN 5-4 MIN. |
| | | | 9.5' TRICONE DRILLING | | | | TRICONE DRILLING<br>CUTTINGS SHOW GRAYWACKE |
| GRAYWACKE | | | SAME AS ABOVE<br>CP=5,100 PSI - D | 100 | | 10 | RUN #2 |

ELEVATION: 75, 73, 71, 69, 67, 65, 63, 61, 59
DEPTH: 76, 78, 80, 82, 84, 86, 88, 90





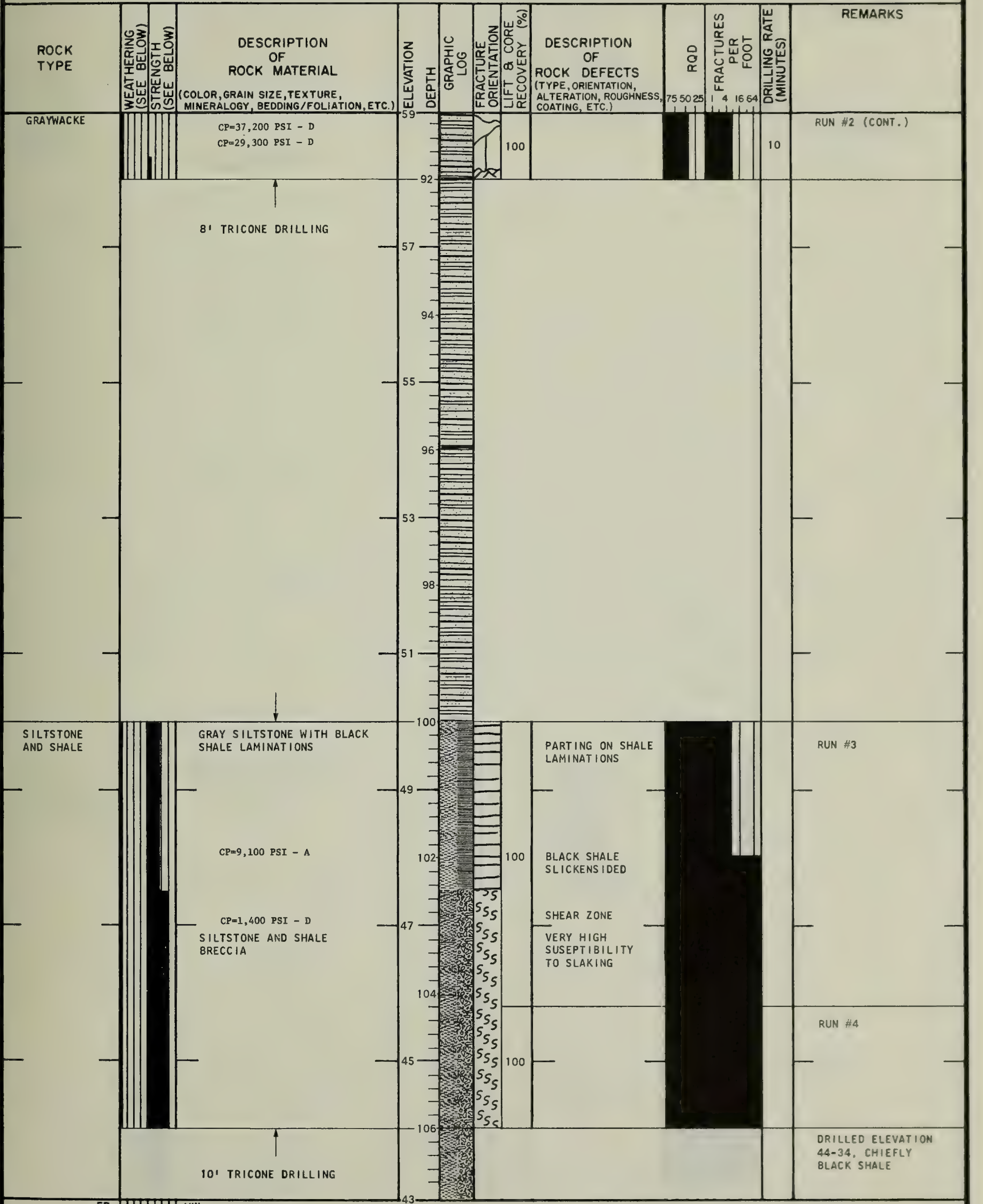
FR SW MW HW XW
VW W MS S VS

# LOG OF BORING

DAMES & MOORE

PLATE A-1F/1

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 6
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH WITH REVERT SLURRY
LOCATION 29th. AVE. NEAR LAKE STREET
ELEV. 150
PAGE 2 OF 6



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| GRAYWACKE | CP=37,200 PSI - D<br>CP=29,300 PSI - D | 59 | 92 | 100 | | 10 | RUN #2 (CONT.) |
| | 8' TRICONE DRILLING | 57<br>55<br>53<br>51 | 94<br>96<br>98<br>100 | | | | |
| SILTSTONE AND SHALE | GRAY SILTSTONE WITH BLACK SHALE LAMINATIONS<br>CP=9,100 PSI - A | 49 | 102 | 100 | PARTING ON SHALE LAMINATIONS<br>BLACK SHALE SLICKENSIDED | | RUN #3 |
| | CP=1,400 PSI - D<br>SILTSTONE AND SHALE BRECCIA | 47 | 104 | | SHEAR ZONE<br>VERY HIGH SUSCEPTIBILITY TO SLAKING | | |
| | | 45 | 106 | 100 | | | RUN #4 |
| | 10' TRICONE DRILLING | 43 | | | | | DRILLED ELEVATION 44-34, CHIEFLY BLACK SHALE |

FR SW MW HW XW

VW W MS S VS

# LOG OF BORING

DAMES & MOORE

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 6
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH WITH REVERT SLURRY
LOCATION 29th. AVE. NEAR LAKE STREET
ELEV. 150
PAGE 3 OF 6

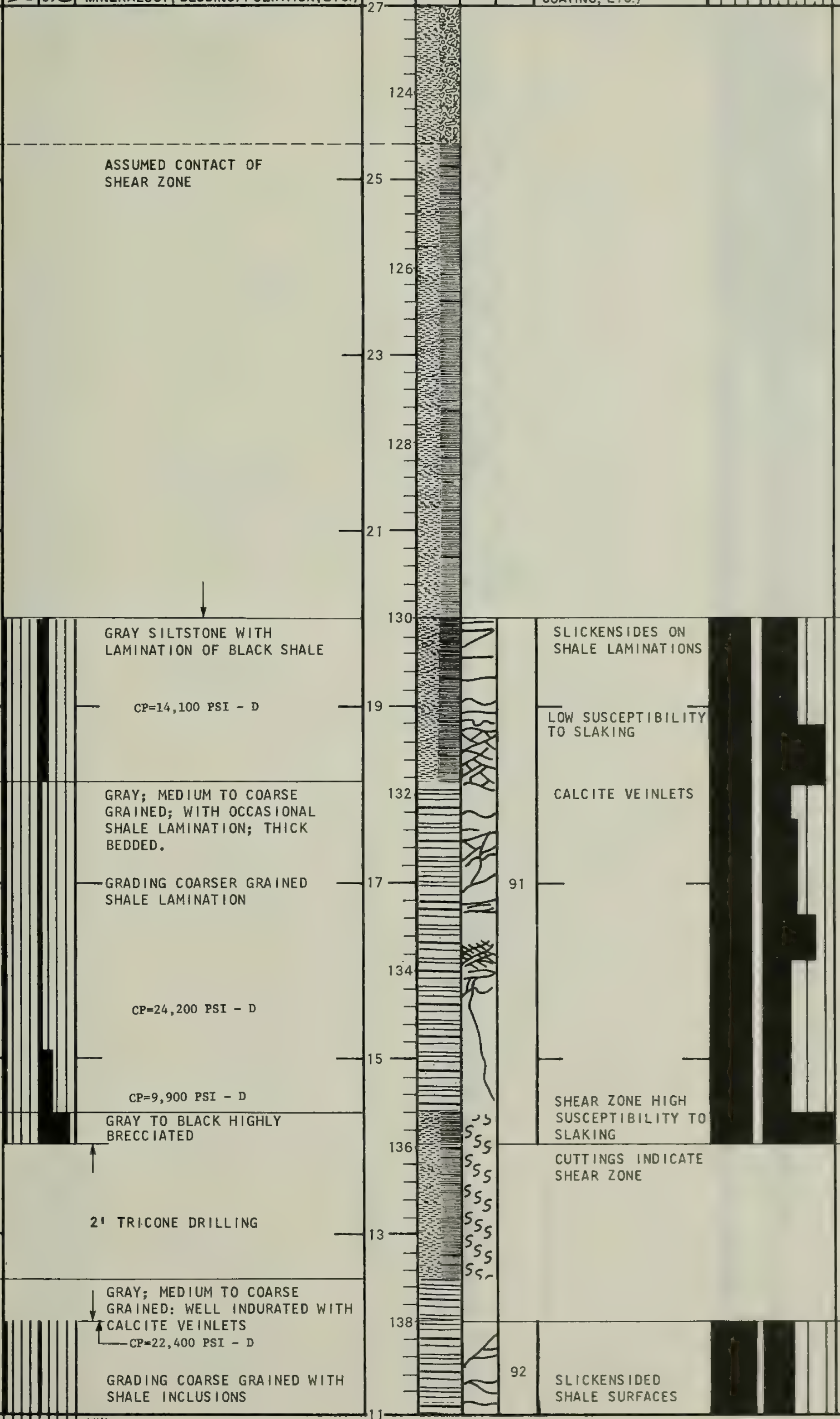
| ROCK TYPE | WEATHERING (SEE BELOW) | STRENGTH (SEE BELOW) | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | GRAPHIC LOG | FRACTURE ORIENTATION | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | RQD 75 50 25 | FRACTURES PER FOOT 1 4 16 64 | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SILTSTONE AND SHALE | | | 10' TRICONE DRILLING CONTINUED | 43<br>41<br>39 | 108<br>110 | | | | | | | | DRILLED ELEVATION 44-34 CHIEFLY BLACK SHALE |
| GRAYWACKE | | | ASSUMED CONTACT | 37<br>35 | 112<br>114 | | | | | | | | |
| GRAYWACKE | | | GRAY; FINE GRAINED WELL INDURATED | | 116 | | | | | | | | RUN #5 |
| SHEARED GRAYWACKE, SILTSTONE AND SHALE WITH CLAY BINDER | | | GRAY TO BLACK HIGHLY BRECCIATED | 33<br>31 | 118<br>120 | | | 10 | SHEAR ZONE HIGHLY BRECCIATED GRAYWACKE SILTSTONE AND SHALE WITH CLAY BINDER HIGH SUSCEPTIBILITY TO SLAKING | | | | |
| | | | | 29 | 122 | | | 100 | HIGH SUSCEPTIBILITY TO SLAKING | | | | RUN #6 |
| | | | TRICONE DRILLING | 27 | | | | | | | | | |

FR — SW — MW — HW — XW
VW — W — MS — S — VS

LOG OF BORING

**DAMES & MOORE**

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 6
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH WITH REVERT SLURRY
LOCATION 29th. AVE. NEAR LAKE STREET
ELEV. 150
PAGE 4 OF 6



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | REMARKS |
|---|---|---|---|---|---|---|
| SHEARED SILTSTONE AND SHALE | | 27 | 124 | | | DRILLED WITH ROCK BIT 7.2' TRICONE DRILLING (CONTINUED) |
| SILTSTONE AND SHALE | ASSUMED CONTACT OF SHEAR ZONE | 25<br>23<br>21 | 126<br>128 | | | |
| | GRAY SILTSTONE WITH LAMINATION OF BLACK SHALE<br>CP=14,100 PSI - D | 19 | 130 | | SLICKENSIDES ON SHALE LAMINATIONS<br>LOW SUSCEPTIBILITY TO SLAKING | RUN #7 |
| GRAYWACKE | GRAY; MEDIUM TO COARSE GRAINED; WITH OCCASIONAL SHALE LAMINATION; THICK BEDDED.<br>GRADING COARSER GRAINED SHALE LAMINATION<br>CP=24,200 PSI - D<br>CP=9,900 PSI - D | 17<br>15 | 132<br>134 | 91 | CALCITE VEINLETS<br>SHEAR ZONE HIGH SUSCEPTIBILITY TO SLAKING | |
| SHEARED SILTSTONE AND SHALE WITH CLAY BINDER | GRAY TO BLACK HIGHLY BRECCIATED<br>2' TRICONE DRILLING | 13 | 136 | | CUTTINGS INDICATE SHEAR ZONE | DRILLED WITH ROCK BIT CUTTINGS SHOWED BLACK SHALE<br>HARD DRILLING |
| GRAYWACKE | GRAY; MEDIUM TO COARSE GRAINED: WELL INDURATED WITH CALCITE VEINLETS<br>CP=22,400 PSI - D<br>GRADING COARSE GRAINED WITH SHALE INCLUSIONS | 11 | 138 | 92 | SLICKENSIDED SHALE SURFACES | RUN #8 |

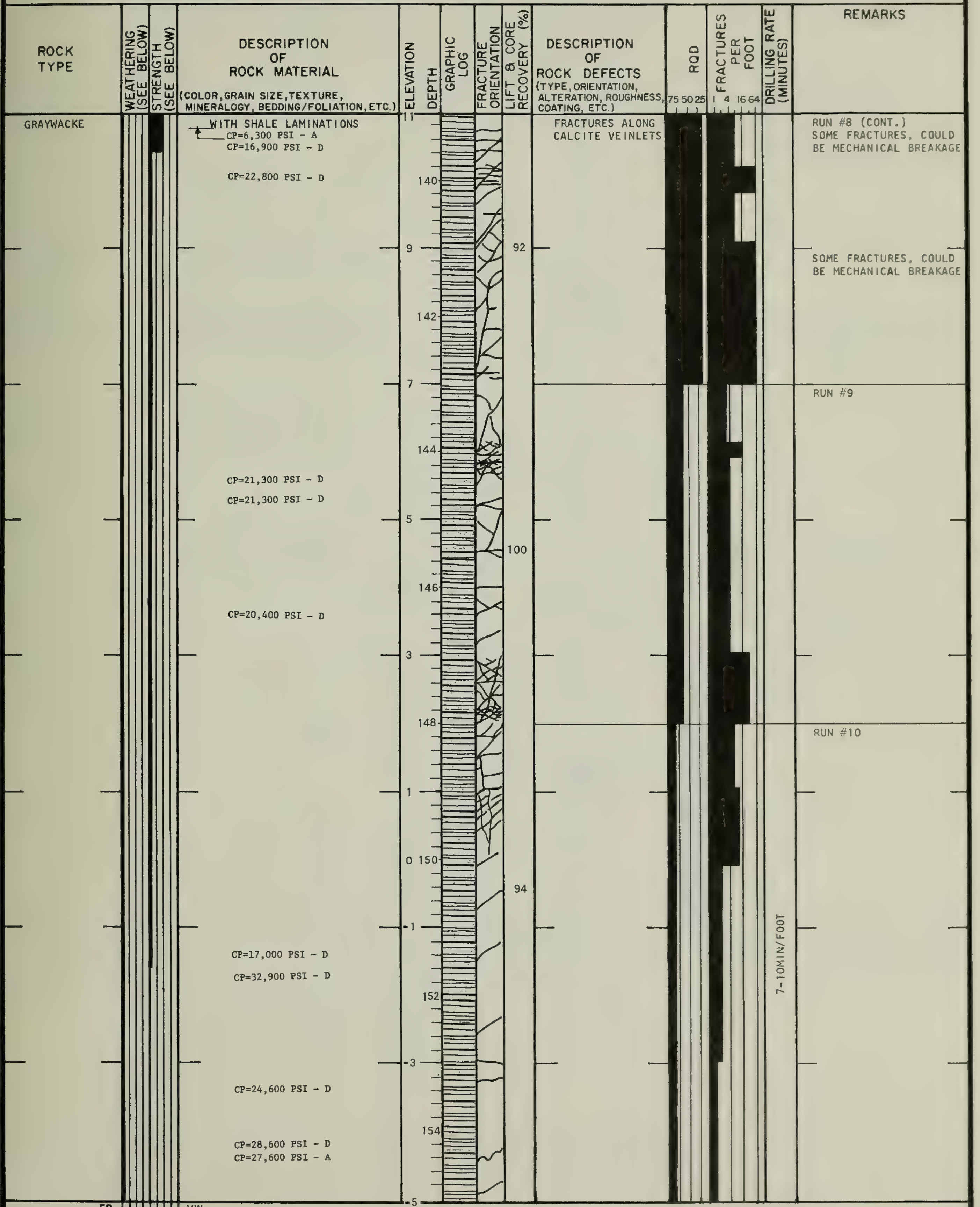
FR SW MW HW XW
VW W MS S VS

## LOG OF BORING

DAMES & MOORE

PLATE A-1F/4

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 6
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH WITH REVERT SLURRY
LOCATION 29th. AVE. NEAR LAKE STREET
ELEV. 150
PAGE 5 OF 6



GRAYWACKE

WITH SHALE LAMINATIONS
CP=6,300 PSI - A
CP=16,900 PSI - D
CP=22,800 PSI - D
CP=21,300 PSI - D
CP=21,300 PSI - D
CP=20,400 PSI - D
CP=17,000 PSI - D
CP=32,900 PSI - D
CP=24,600 PSI - D
CP=28,600 PSI - D
CP=27,600 PSI - A

FRACTURES ALONG CALCITE VEINLETS

7-10MIN/FOOT

RUN #8 (CONT.) SOME FRACTURES, COULD BE MECHANICAL BREAKAGE

SOME FRACTURES, COULD BE MECHANICAL BREAKAGE

RUN #9

RUN #10

FR
SW
MW
HW
XW

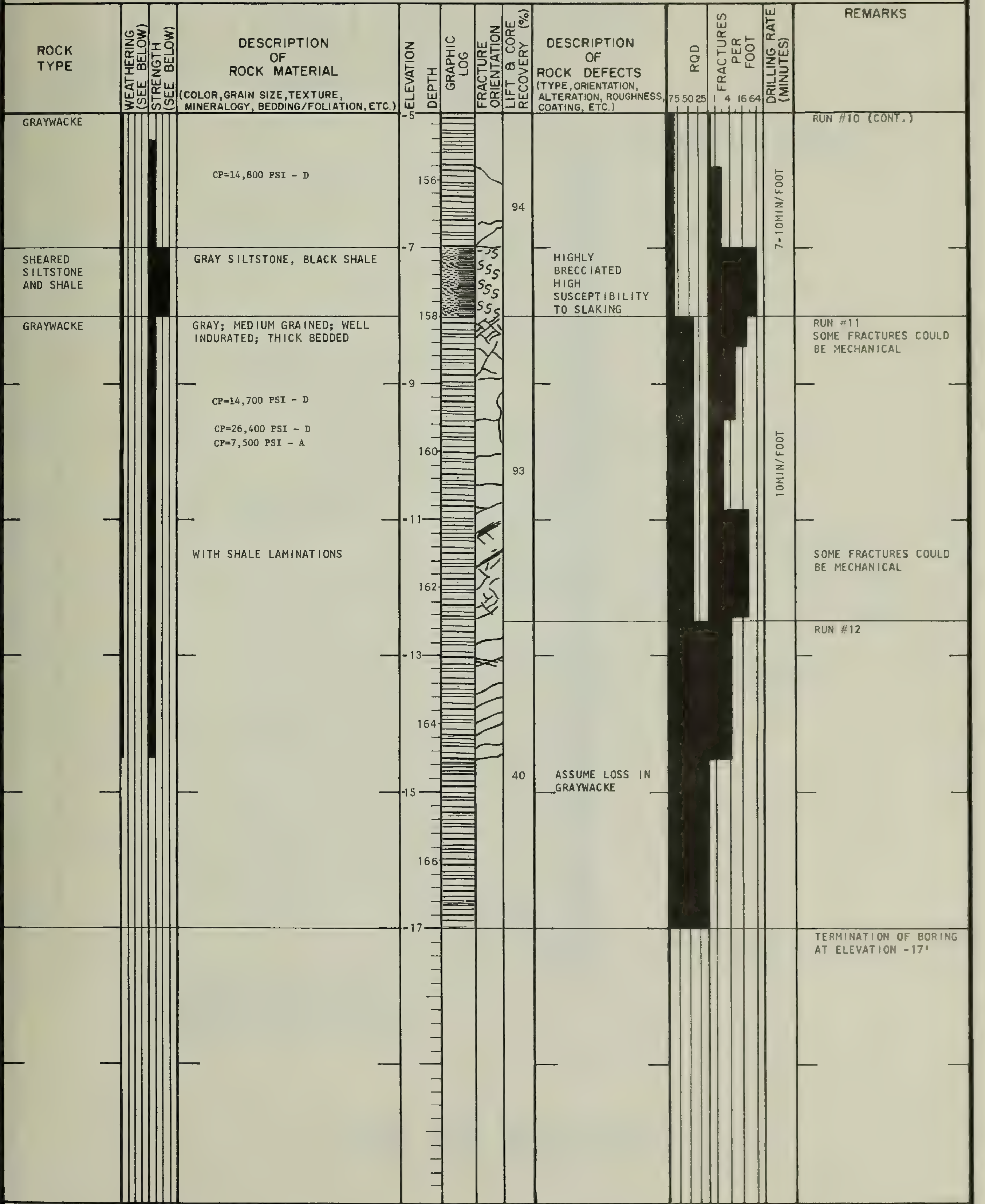
VW
W
MS
S
VS

## LOG OF BORING

**DAMES & MOORE**

PLATE A-1F/5

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 6
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH WITH REVERT SLURRY
LOCATION 29th. AVE. NEAR LAKE STREET
ELEV. 150
PAGE 6 OF 6



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| GRAYWACKE | CP=14,800 PSI - D | -5 | 156 | 94 |  | 7-10MIN/FOOT | RUN #10 (CONT.) |
| SHEARED SILTSTONE AND SHALE | GRAY SILTSTONE, BLACK SHALE | -7 |  |  | HIGHLY BRECCIATED<br>HIGH SUSCEPTIBILITY TO SLAKING |  |  |
| GRAYWACKE | GRAY; MEDIUM GRAINED; WELL INDURATED; THICK BEDDED<br>CP=14,700 PSI - D<br>CP=26,400 PSI - D<br>CP=7,500 PSI - A<br>WITH SHALE LAMINATIONS | -9<br>-11 | 158<br>160<br>162 | 93 |  | 10MIN/FOOT | RUN #11<br>SOME FRACTURES COULD BE MECHANICAL<br>SOME FRACTURES COULD BE MECHANICAL |
|  |  | -13<br>-15 | 164<br>166 | 40 | ASSUME LOSS IN GRAYWACKE |  | RUN #12 |
|  |  | -17 |  |  |  |  | TERMINATION OF BORING AT ELEVATION -17' |

FR SW MW HW XW
VW W MS S VS

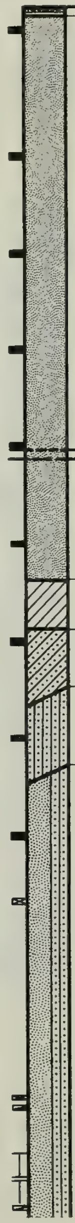
## LOG OF BORING

**DAMES & MOORE**

PLATE A-1F/6

## BORING 7
DRILLED 12/21-28/77

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | SHEAR STRENGTH TEST RESULTS, LABORATORY: TYPE OF TEST | SHEAR STRENGTH TEST RESULTS, LABORATORY: NORMAL OR CONFINING PRESSURE (PSF) | SHEAR STRENGTH TEST RESULTS, LABORATORY: PEAK SHEAR STRENGTH (PSF) | SHEAR STRENGTH TEST RESULTS, FIELD: TORVANE (PSF) | SHEAR STRENGTH TEST RESULTS, FIELD: PENETROMETER (PSF) | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT) or (HYD. PRESS., PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| +150 | | | | | | | | | | | | | | |
| | | 5 | 107 | | | | | | | | | U | 100 | 25 |
| +140 | | | | | | | | | | | | | | |
| | SA (2%) | 15 | 103 | | | DS/CD | 1700 | 1490 | | | | U | 100 | 76 |
| +130 | | | | | | | | | | | | | | |
| | | 19 | 105 | | | | | | | | | U | 89 | 105 |
| +120 | | | | | | | | | | | | | | |
| | | 18 | 108 | | | DS/CD | 3900 | 3350 | | | | U | 100 | 70/6" |
| +110 | | | | | | | | | | | | | | |
| | SA (1%) | 21 | 99 | | | | | | | | | U | 100 | 100/4" |
| +100 | | | | | | | | | | | | | | |
| | | 19 | 107 | | | DS/CD | 6000 | 4980 | | | | U | 100 | 37/2" |
| +90 | | | | | | | | | | | | | | |
| | | 18 | 113 | | | | | | | | | U | 100 | 28 |
| +80 | | | | | | | | | | | | | | |
| | SA (22%) | 22 | 108 | | | | | | | | | U | 100 | 60/6" |
| +70 | | | | | | | | | | | | | | |
| | PERM<br>SA (12%) | 19 | 111 | | | DS/CD | 7100 | 5400 | | | | U | 92 | 53/6" |
| +60 | | | | | | | | | | | | | | |
| | | 15 | 121 | | | | | | | | | U | 90 | 100/4.5" |
| +50 | | | | | | | | | | | | | | |
| +40 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | U<br>SPT | 80<br>100 | 182/10" |
| +30 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | PT<br>PT<br>SPT | 0 | 100 |



ELEVATION +147'

| | |
|---|---|
| | ASPHALT, CONCRETE, AND BASE ROCK |
| SP | DARK BROWN FINE SAND (MEDIUM DENSE)(DUNE SAND)<br>(GRADING TO VERY DENSE)<br>(WATER LEVEL 6/9/18 2/15/78) |
| CL | DARK BROWN SILTY CLAY (COLMA FORMATION) |
| SC | BROWN CLAYEY FINE SAND (MEDIUM DENSE) (COLMA FORMATION) |
| SM | DARK BROWN SILTY FINE SAND (VERY DENSE) |
| SP/SM | DARK BROWN TO REDDISH BROWN SLIGHTLY SILTY FINE SAND (VERY DENSE)<br>(OCCASIONAL TRACE OF FINE GRAVEL) |

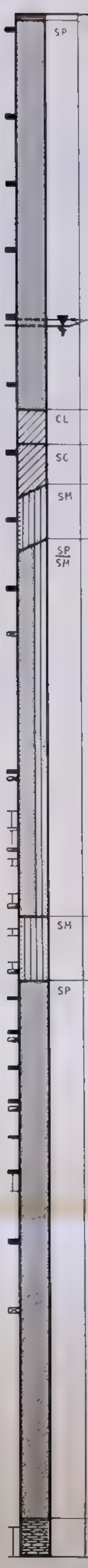
1. SAMPLING RESISTANCE:
   SPT DRIVEN BY 140# HAMMER FALLING 30"
   U AND TW DRIVEN BY 340# SLIPJARS FALLING 18"
2. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED
   ON OFFICIAL CITY GRADE.

# LOG OF BORING

**DAMES & MOORE**

# BORING 7
DRILLED 12/21-28/77

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS |  | SHEAR STRENGTH TEST RESULTS |  |  |  |  | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT) or (HYD. PRESS. PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | LABORATORY |  |  | FIELD |  |  |  |  |  |
|  |  |  |  | LIQUID LIMIT | PLASTIC LIMIT | TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | TORVANE (PSF) | PENETROMETER (PSF) |  |  |  |  |
| +150 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | 5 | 107 |  |  |  |  |  |  |  |  | U | 100 | 25 |
| +140 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| +130 | SA (2%) | 15 | 103 |  |  | DS/CD | 1700 | 1490 |  |  |  | U | 100 | 76 |
| +120 |  | 19 | 105 |  |  |  |  |  |  |  |  | U | 89 | 105 |
| +110 |  | 18 | 108 |  |  | DS/CD | 3900 | 3350 |  |  |  | U | 100 | 70/6" |
| +100 | SA (1%) | 21 | 99 |  |  |  |  |  |  |  |  | U | 100 | 100/4" |
| +90 |  | 19 | 107 |  |  | DS/CD | 6000 | 4980 |  |  |  | U | 100 | 37/2" |
| +80 |  | 18 | 113 |  |  |  |  |  |  |  |  | U | 100 | 28 |
| +70 | SA (22%) | 22 | 108 |  |  |  |  |  |  |  |  | U | 100 | 60/6" |
| +60 | PERM<br>SA (12%) | 19 | 111 |  |  | DS/CD | 7100 | 5400 |  |  |  | U | 92 | 53/6" |
|  |  | 15 | 121 |  |  |  |  |  |  |  |  | U | 90 | 100/4.5" |
| +50 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| +40 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  | U<br>SPT | 80<br>100 | 182/10" |
| +30 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  | PT<br>PT<br>SPT<br>PT | 0 | 100/6" |
| +20 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  | PT<br>SPT | 100 | 100/6" |
| +10 |  |  |  |  |  |  |  |  |  |  |  | PT |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  | PT<br>SPT | 100 | 100/7" |
| 0 |  | 25 | 99 |  |  | DS/CD | 10,000 | 8280 |  |  |  | U | 100 | 50/2" |
|  |  |  |  |  |  |  |  |  |  |  |  | U<br>SPT | 100<br>100 | 75/2"<br>117/6" |
| -10 | SA (4%) | 24 | 104 |  |  |  |  |  |  |  |  | U | 100 | 50/2" |
|  |  | 24 | 100 |  |  | DS/CD | 10,900 | 8160 |  |  |  | U<br>SPT | 100<br>100 | 50/2"<br>120/6" |
|  |  |  |  |  |  |  |  |  |  |  |  | U | 100 | 150/6" |
| -20 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  | U<br>PT | 67<br>90 | 150/6" |
| -30 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | 14 | 110 |  |  |  |  |  |  |  |  | U | 100 | 50/3" |
| -40 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  | U | 67 | 50/3" |
| -50 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| -60 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| -70 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| -80 |  |  |  |  |  |  |  |  |  |  | 3.5 | NX | 0 |  |



ELEVATION +147'

ASPHALT, CONCRETE, AND BASE ROCK

SP DARK BROWN FINE SAND (MEDIUM DENSE) (DUNE SAND)

(GRADING TO VERY DENSE)

(WATER LEVEL 6/9/18 2/15/78)

CL DARK BROWN SILTY CLAY (COLMA FORMATION)

SC BROWN CLAYEY FINE SAND (MEDIUM DENSE) (COLMA FORMATION)

SM DARK BROWN SILTY FINE SAND (VERY DENSE)

SP/SM DARK BROWN TO REDDISH BROWN SLIGHTLY SILTY FINE SAND (VERY DENSE)

(OCCASIONAL TRACE OF FINE GRAVEL)

SM DARK BROWN TO REDDISH BROWN SLIGHTLY SILTY FINE SAND (VERY DENSE)

SP DARK BROWN TO REDDISH BROWN MEDIUM FINE SAND (VERY DENSE)

(GRADING SLIGHTLY SILTY)

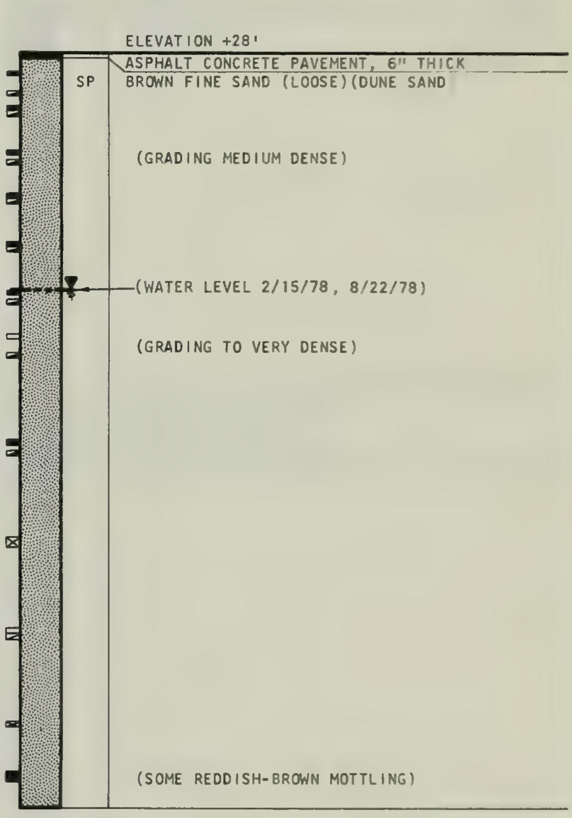
RED-BROWN FRANCISCAN CHERT, STRONG, VERY HIGHLY FRACTURED (RQD=0)

NOTES:
1. SAMPLING RESISTANCE:
SPT DRIVEN BY 140# HAMMER FALLING 30"
U AND TW DRIVEN BY 340# SLIPJARS FALLING 18"
2. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED ON OFFICIAL CITY GRADE.

# LOG OF BORING

## BORING 8
DRILLED 12/20-28/77

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS |  | SHEAR STRENGTH TEST RESULTS |  |  |  |  | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD.PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | LABORATORY |  |  | FIELD |  |  |  |  |  |
|  |  |  |  | LIQUID LIMIT | PLASTIC LIMIT | TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | TORVANE (PSF) | PENETROMETER (PSF) |  |  |  |  |
| +30 |  | 4 | 99 |  |  |  |  |  |  |  |  | U | 100 | 10 |
|  |  | 5 | 98 |  |  | DS/CD | 700 | 460 |  |  |  | SPT | 100 | 5 |
|  |  |  |  |  |  |  |  |  |  |  |  | U | 100 | 8 |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 56 | 5 |
| +20 |  | 5 | 93 |  |  | DS/CD | 1200 | 810 |  |  |  | U | 78 | 18 |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 44 | 13 |
|  | SA (1%) | 5 | 100 |  |  |  |  |  |  |  |  | U | 78 | 23 |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 44 | 11 |
| +10 |  | 5 | 95 |  |  | DS/CD | 2200 | 1440 |  |  |  | U | 83 | 28 |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 56 | 17 |
|  |  |  |  |  |  |  |  |  |  |  |  | U | 67 | 24 |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 44 | 9 |
| 0 |  |  |  |  |  |  |  |  |  |  |  | U | 0 | 100/4" |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 100 | 66 |
| -10 | SA (1%) | 22 | 106 |  |  |  |  |  |  |  |  | U | 100 | 52/6" |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 78 | 86 |
| -20 |  |  |  |  |  |  |  |  |  |  |  | U | 44 |  |
| -30 |  |  |  |  |  |  |  |  |  |  |  | U | 0 | 26 |
|  |  |  |  |  |  |  |  |  |  |  |  | SPT | 0 | 24 |
| -40 |  | 24 | 97 |  |  |  |  |  |  |  |  | U | 83 | 106 |
|  |  |  |  |  |  |  |  |  |  |  |  | U | 100 | 150/8" |
| -50 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |


ELEVATION +28'
ASPHALT CONCRETE PAVEMENT, 6" THICK
SP
BROWN FINE SAND (LOOSE)(DUNE SAND
(GRADING MEDIUM DENSE)
(WATER LEVEL 2/15/78, 8/22/78)
(GRADING TO VERY DENSE)
(SOME REDDISH-BROWN MOTTLING)

NOTES:

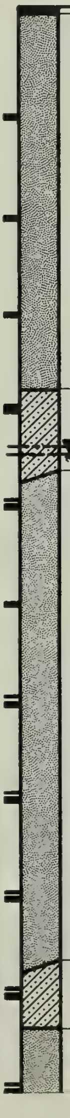
1. SAMPLING RESISTANCE:
   U AND SPT DRIVEN BY 140# HAMMER FALLING 30"
2. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED
   ON OFFICIAL CITY GRADE

# LOG OF BORING

## BORING 9

DRILLED 12/22-27/77

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | SHEAR STRENGTH TEST RESULTS, LABORATORY: TYPE OF TEST | SHEAR STRENGTH TEST RESULTS, LABORATORY: NORMAL OR CONFINING PRESSURE (PSF) | SHEAR STRENGTH TEST RESULTS, LABORATORY: PEAK SHEAR STRENGTH (PSF) | SHEAR STRENGTH TEST RESULTS, FIELD: TORVANE (PSF) | SHEAR STRENGTH TEST RESULTS, FIELD: PENETROMETER (PSF) | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD. PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| +170 | | | | | | | | | | | | | | |
| +160 | | | | | | | | | | | | | | |
| +150 | | 16 | 105 | | | | | | | | | U | 67 | 25 |
| +140 | | 20 | 103 | | | | | | | | | U | 56 | 21 |
| +130 | | 20 | 99 | | | | | | | | | U | 67 | 25 |
| +120 | SA (41%) | 15 | 116 | | | | | | | | | U | 75 | 13 |
| +110 | | 15 | 111 | | | | | | | | | U | 90 | 95/9" |
| +100 | | | | | | | | | | | | U | 76 | 94/11" |
| +90 | | 20 | 108 | | | | | | | | | U | 72 | 90 |
| +80 | | 25 | 102 | | | | | | | | | U | 75 | 93 |
| +70 | | 23 | 106 | | | | | | | | | U | 75 | 74 |
| +60 | SA (40%) | 16 | 115 | | | | | | | | | U | 78 | 23 |
| +50 | | 20 | 107 | | | DS/CD | 10 100 | 8760 | | | | U | 82 | 94 |



ELEVATION +161

ASPHALT PAVEMENT, 4" THICK

| | |
|---|---|
| SP | BROWN TO YELLOW BROWN FINE SAND (MEDIUM DENSE)<br>(DUNE SAND) |
| SC | YELLOW BROWN CLAYEY FINE SAND WITH DARK BROWN MOTTLING (MEDIUM DENSE)<br>(COLMA FORMATION)<br>(WATER LEVEL 8/22/78, 2/15/78) |
| SP | BROWN FINE SAND WITH TRACE OF CLAY (VERY DENSE)<br>(GRADING REDDISH-BROWN) |
| SC | BROWN TO YELLOW BROWN CLAYEY FINE SAND (MEDIUM DENSE) |
| SP | BROWN FINE SAND WITH TRACE OF CLAY (VERY DENSE) |

SPT DRIVEN BY 140# HAMMER FALLING 30"
U SAMPLER DRIVEN BY 275# SLIPJARS FALLING 30"
2. ELEVATIONS REFER TO SF DATUM AND ARE BASED ON
OFFICIAL CITY GRADE

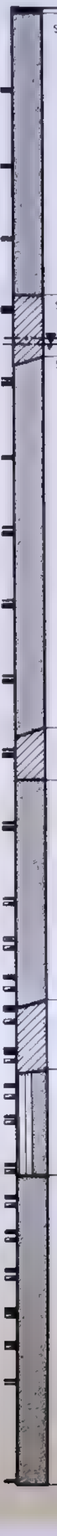
# LOG OF BORING

DAMES & MOORE

## BORING 9

DRILLED 12/22-27/77

|  |  |  |  | ATTERBERG LIMITS |  | SHEAR STRENGTH TEST RESULTS |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | LABORATORY |  |  | FIELD |  |  |  |  |  |
| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | LIQUID LIMIT | PLASTIC LIMIT | TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | TORVANE (PSF) | PENETROMETER (PSF) | CORING RATE (MIN/FT) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT) or (HYD PRESS.,PSI) |
| +170 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| +160 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| +150 |  | 16 | 105 |  |  |  |  |  |  |  |  | U | 67 | 25 |
| +140 |  | 20 | 103 |  |  |  |  |  |  |  |  | U | 56 | 21 |
| +130 |  | 20 | 99 |  |  |  |  |  |  |  |  | U | 67 | 25 |
| +120 | SA<br>(41 ) | 15 | 116 |  |  |  |  |  |  |  |  | U | 75 | 13 |
| +110 |  | 15 | 111 |  |  |  |  |  |  |  |  | U | 90 | 95/9" |
| +100 |  |  |  |  |  |  |  |  |  |  |  | U | 76 | 94/11" |
| +90 |  | 20 | 108 |  |  |  |  |  |  |  |  | U | 72 | 90 |
| +80 |  | 25 | 102 |  |  |  |  |  |  |  |  | U | 75 | 93 |
| +70 |  | 23 | 106 |  |  |  |  |  |  |  |  | U | 75 | 74 |
| +60 | SA<br>(40%) | 16 | 115 |  |  |  |  |  |  |  |  | U | 78 | 23 |
| +50 |  | 20 | 107 |  |  | DS/CD | 10,100 | 8760 |  |  |  | U | 82 | 94/11" |
| +40 |  |  |  |  |  |  |  |  |  |  |  | U<br>SPT | 50<br>100 | 50/6"<br>85/6" |
|  |  |  |  |  |  |  |  |  |  |  |  | U<br>SPT | 75<br>100 | 95<br>80/6" |
| +30 |  |  |  |  |  |  |  |  |  |  |  | U<br>SPT | 78<br>100 | 38<br>97 |
|  | SA<br>(22%) | 19 | 112 |  |  | DS/CD | 11,900 | 8640 |  |  |  | U<br>SPT | 100 | 38<br>90/9" |
| +20 |  | 19 | 105 |  |  |  |  |  |  |  |  | U<br>SPT | 78<br>100 | 32<br>50/4" |
|  | PERM<br>SA<br>(6%) | 26 | 97 |  |  | DS/CD | 12,000 | 8160 |  |  |  | U<br>SPT | 78<br>91 | 77<br>50/5" |
| +10 |  |  |  |  |  |  |  |  |  |  |  | U<br>SPT | 91<br>89 | 100/5"<br>100/5" |
|  |  | 26 | 100 |  |  | DS/CD | 12,000 | 8160 |  |  |  | U<br>SPT | 78<br>33 | 72<br>100/6" |
| 0 |  |  |  |  |  |  |  |  |  |  |  | U<br>SPT | 82<br>73 | 50/5"<br>50/5" |
|  |  | 17 | 109 |  |  | DS/CD | 12,000 | 9250 |  |  |  | U<br>SPT | 89<br>78 | 50/3"<br>50/3" |
| -10 |  | 21 | 109 |  |  |  |  |  |  |  |  | U<br>SPT | 89<br>80 | 50/3"<br>50/4" |
|  |  |  |  |  |  |  |  |  |  |  |  | U<br>SPT | 90 | 50/4"<br>50/5" |
| -20 |  |  |  |  |  |  |  |  |  |  |  | U<br>SPT | 83<br>100 | 73/6"<br>100/4" |
|  |  | 18 | 118 |  |  |  |  |  |  |  |  | U | 100 | 30/2" |
| -30 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| -40 |  |  |  |  |  |  |  |  |  |  |  | U | 100 | 100/6" |



ELEVATION +161

ASPHALT PAVEMENT, 4" THICK

| | |
|---|---|
| SP | BROWN TO YELLOW BROWN FINE SAND (MEDIUM DENSE) (DUNE SAND) |
| SC | YELLOW BROWN CLAYEY FINE SAND WITH DARK BROWN MOTTLING (MEDIUM DENSE)<br>(COLMA FORMATION)<br>(WATER LEVEL 8/22/78, 2/15/7[illegible]) |
| SP | BROWN FINE SAND WITH TRACE OF CLAY (VERY DENSE)<br>(GRADING REDDISH-BROWN) |
| SC | BROWN TO YELLOW BROWN CLAYEY FINE SAND (MEDIUM DENSE) |
| SP | BROWN FINE SAND WITH TRACE OF CLAY (VERY DENSE)<br>(GRADING REDDISH-BROWN, SLIGHTLY MORE CLAYEY) |
| SC | REDDISH BROWN CLAYEY FINE SAND (VERY DENSE) |
| SM/SP | BROWN SLIGHTLY SILTY FINE SAND (VERY DENSE)<br>(GRADING MORE SILTY) |
| SP | BROWN FINE SAND WITH OCCASIONAL IRON OXIDE STAINING (VERY DENSE)<br>(GRADING WITH TRACE OF CLAY)<br>(TRACE DECAYED VEGETATION)<br>(GRADING REDDISH-BROWN) |

NOTES:

1. SAMPLING RESISTANCE:
   SPT DRIVEN BY 140# HAMMER FALLING 30"
   U SAMPLER DRIVEN BY 275# SLIPJARS FALLING 30"
2. ELEVATIONS REFER TO SF DATUM AND ARE BASED ON OFFICIAL CITY GRADE

# LOG OF BORING

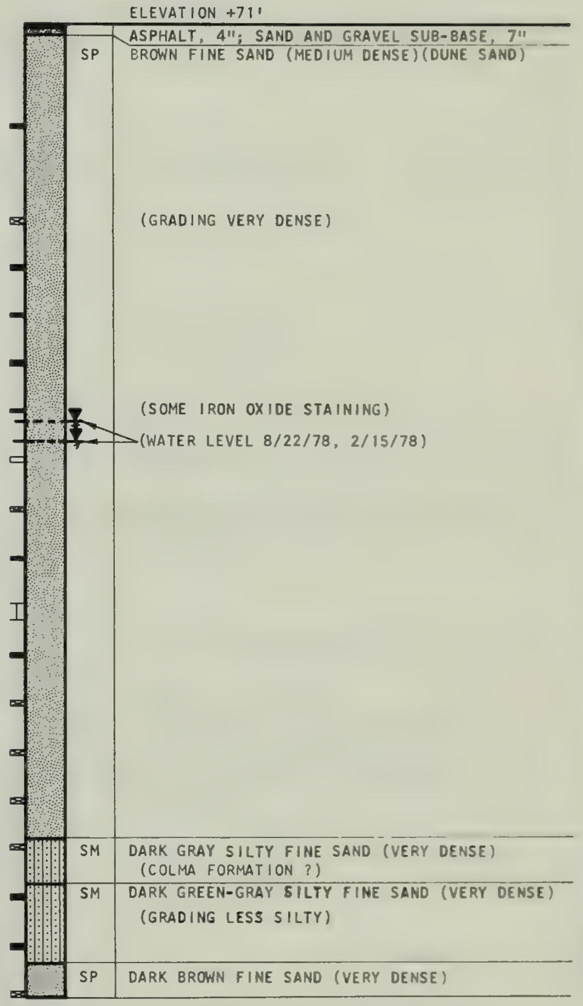
**DAMES & MOORE**

PLATE A-11

## BORING 10

DRILLED 1/19-20/78

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | SHEAR STRENGTH TEST RESULTS, LABORATORY: TYPE OF TEST | SHEAR STRENGTH TEST RESULTS, LABORATORY: NORMAL OR CONFINING PRESSURE (PSF) | SHEAR STRENGTH TEST RESULTS, LABORATORY: PEAK SHEAR STRENGTH (PSF) | SHEAR STRENGTH TEST RESULTS, FIELD: TORVANE (PSF) | SHEAR STRENGTH TEST RESULTS, FIELD: PENETROMETER (PSF) | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD.PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| +80 | | | | | | | | | | | | | | |
| +70 | | | | | | | | | | | | | | |
| +60 | | 4 | 100 | | | | | | | | | U | 100 | 29 |
| +50 | | | | | | | | | | | | U | 50 | 90/6" |
| | | 12 | 107 | | | | | | | | | U | 100 | 72 |
| +40 | | 16 | 101 | | | DS/CD | 3450 | 2520 | | | | U | 100 | 75/6" |
| | PERM<br>SA<br>(1%) | 16 | 109 | | | | | | | | | U | 100 | 70/6" |
| +30 | | 19 | 104 | | | | | | | | | U | 80 | 60/6" |
| | | | | | | | | | | | | U | 0 | 25/1" |
| +20 | | 19 | | | | | | | | | | U | 100 | 60/3" |
| | | 20 | 103 | | | DS/CD | 5800 | 4440 | | | | U | 100 | 60/3" |
| +10 | | | | | | | | | | | | PT | 0 | |
| | | 18 | 103 | | | DS/CD | 6500 | 4920 | | | | U | 100 | 60/4" |
| 0 | | | | | | | | | | | | U | 85 | 40/2" |
| | | | | | | | | | | | | U | 50 | 100/6" |
| -10 | | | | | | | | | | | | U | 100 | 100/4" |
| | SA<br>(16%) | 19 | | | | | | | | | | U | 33 | 70 |
| -20 | SA<br>(35%) | 21 | 109 | | | | | | | | | U | 100 | 75/8" |
| | | 22 | 106 | | | | | | | | | U | 71 | 40/2.5" |
| -30 | | | | | | | | | | | | U | 100 | 100/4.5" |
| -40 | | | | | | | | | | | | | | |



ELEVATION +71'

ASPHALT, 4"; SAND AND GRAVEL SUB-BASE, 7"

SP BROWN FINE SAND (MEDIUM DENSE)(DUNE SAND)

(GRADING VERY DENSE)

(SOME IRON OXIDE STAINING)

(WATER LEVEL 8/22/78, 2/15/78)

SM DARK GRAY SILTY FINE SAND (VERY DENSE) (COLMA FORMATION ?)

SM DARK GREEN-GRAY SILTY FINE SAND (VERY DENSE) (GRADING LESS SILTY)

SP DARK BROWN FINE SAND (VERY DENSE)

NOTES:

1. SAMPLING RESISTANCE:
   U SAMPLER DRIVEN BY 340# SLIPJARS FALLING 18"
2. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED ON OFFICIAL CITY GRADE.

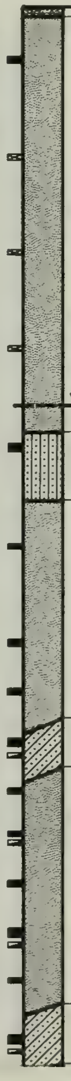
# LOG OF BORING

**DAMES & MOORE**

PLATE A-1J

## BORING 11
DRILLED 12/29/77-1/5/78

| ATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS |  | SHEAR STRENGTH TEST RESULTS |  |  |  |  | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT) or (HYD. PRESS., PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | LABORATORY |  |  | FIELD |  |  |  |  |  |
|  |  |  |  | LIQUID LIMIT | PLASTIC LIMIT | TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | TORVANE (PSF) | PENETROMETER (PSF) |  |  |  |  |
| +140 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| +130 |  | 4 | 102 |  |  |  |  |  |  |  |  | U | 100 | 35 |
| +120 |  |  |  |  |  |  |  |  |  |  |  | TW | 44 | 103 |
| +110 |  |  |  |  |  |  |  |  |  |  |  | U | 89 | 68 |
| +100 |  | 18 |  |  |  |  |  |  |  |  |  | TW | 93 | 90/8" |
| +90 | SA (16%) | 22 | 108 |  |  |  |  |  |  |  |  | TW | 100 | 100/10" |
| +80 |  | 22 | 111 |  |  | DS/CD | 6000 | 5160 |  |  |  | TW | 100 | 65/6" |
| +70 | SA (15%) | 20 | 109 |  |  |  |  |  |  |  |  | TW | 100 | 65/6" |
|  |  | 25 | 103 |  |  |  |  |  |  |  |  | TW | 100 | 90 |
| +60 |  | 20 | 110 |  |  | DS/CD | 7300 | 4380 |  |  |  | TW<br>SPT | 100<br>100 | 25<br>74 |
|  |  | 22 | 106 |  |  |  |  |  |  |  |  | TW | 83 | 65/6" |
| +50 |  | 23 |  |  |  |  |  |  |  |  |  | TW<br>SPT | 67<br>100 | 75/6"<br>112/6" |
|  |  | 20 | 110 |  |  |  |  |  |  |  |  | TW | 83 | 85/6" |
| +40 |  | 24 | 100 |  |  |  |  |  |  |  |  | TW<br>SPT | 82<br>100 | 125/5"<br>150/6" |
|  |  | 21 | 112 |  |  | DS/CD | 9000 | 7560 |  |  |  | U | 82 | 100/5" |
| +30 | SA (29%) | 21 | 109 |  |  |  |  |  |  |  |  | U<br>SPT | 100<br>100 | 50<br>79 |



ELEVATION +133'

2" OF ASPHALT, 5" OF CONCRETE, 2" CRUSHED ROCK

SP BROWN FINE SAND (DENSE)
(DUNE SAND)

(GRADING VERY DENSE)

(WATER LEVEL 2/15/78, 6/8/78)

SM DARK GREEN SILTY FINE SAND (VERY DENSE)
(COLMA FOUNDATION)

SP ORANGE BROWN FINE SAND WITH TRACE OF SILT
(VERY DENSE)

(GRADING REDDISH-BROWN, SLIGHTLY MORE SILTY)

(GRADING LESS SILTY)

SC REDDISH-BROWN CLAYEY FINE SAND (DENSE)

SP REDDISH-BROWN SLIGHTLY SILTY FINE SAND
(VERY DENSE)

(GRADING LESS SILTY)

SC REDDISH-BROWN CLAYEY FINE SAND (VERY DENSE)

NOTES:
1. SAMPLING RESISTANCE:
   SPT DRIVEN BY 140# HAMMER FALLING 30"
   U AND TW DRIVEN BY 340# SLIPJARS FALLING 18"
2. ELEVATION REFER TO S.F. DATUM AND ARE BASED
   ON OFFICIAL CITY GRADE

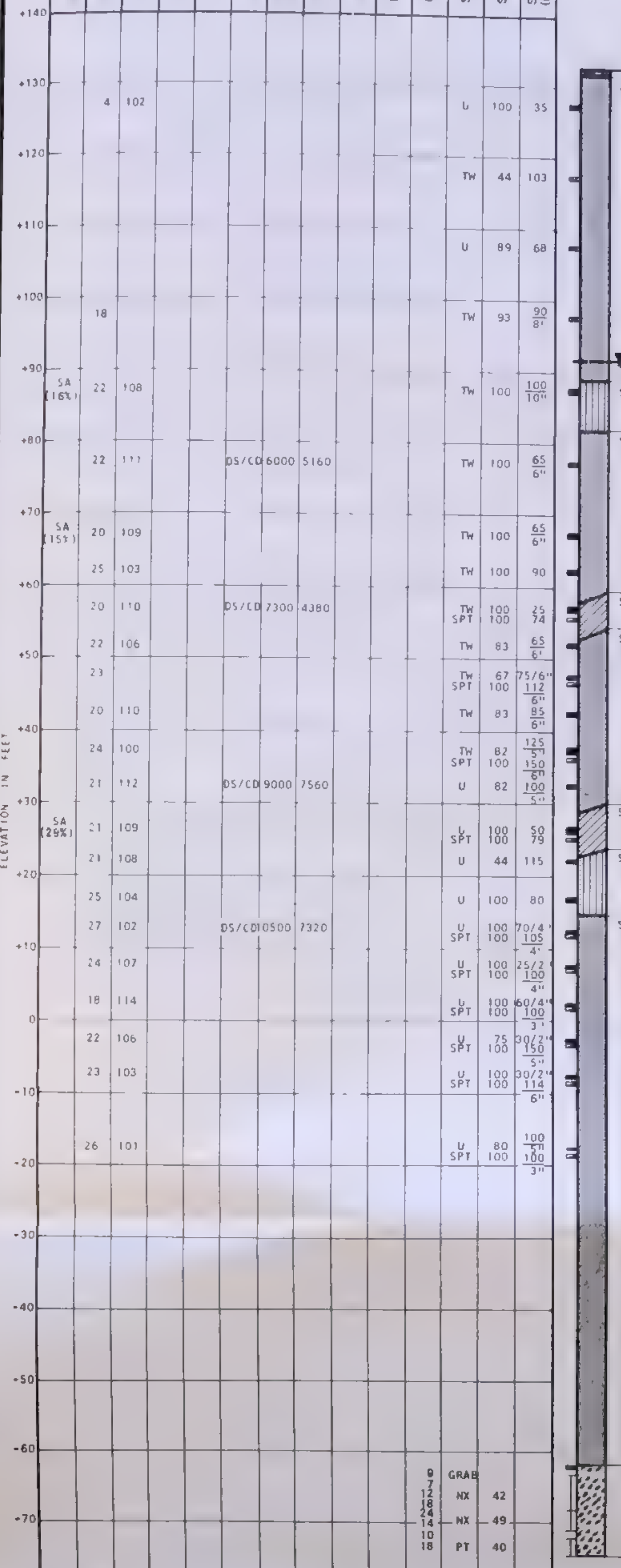
# LOG OF BORING

**DAMES & MOORE**

## BORING 11

DRILLED 12/29/77-1/5/78

| OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS<br>LIQUID LIMIT | PLASTIC LIMIT | SHEAR STRENGTH TEST RESULTS<br>LABORATORY<br>TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | FIELD<br>TORVANE (PSF) | PENETROMETER (PSF) | CORING RATE (MIN/FT) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD PRESS,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 102 | | | | | | | | | U | 100 | 35 |
| | | | | | | | | | | | TW | 44 | 103 |
| | | | | | | | | | | | U | 89 | 68 |
| | 18 | | | | | | | | | | TW | 93 | 90/8' |
| SA (16%) | 22 | 108 | | | | | | | | | TW | 100 | 100/10" |
| | 22 | 111 | | | DS/CD | 6000 | 5160 | | | | TW | 100 | 65/6" |
| SA (15%) | 20 | 109 | | | | | | | | | TW | 100 | 65/6" |
| | 25 | 103 | | | | | | | | | TW | 100 | 90 |
| | 20 | 110 | | | DS/CD | 7300 | 4380 | | | | TW<br>SPT | 100<br>100 | 25<br>74 |
| | 22 | 106 | | | | | | | | | TW | 83 | 65/6' |
| | 23 | | | | | | | | | | TW<br>SPT | 67<br>100 | 75/6"<br>112/6" |
| | 20 | 110 | | | | | | | | | TW | 83 | 85/6" |
| | 24 | 100 | | | | | | | | | TW<br>SPT | 82<br>100 | 125/5"<br>150/6" |
| | 21 | 112 | | | DS/CD | 9000 | 7560 | | | | U | 82 | 100/5" |
| SA (29%) | 21 | 109 | | | | | | | | | U<br>SPT | 100<br>100 | 50<br>79 |
| | 21 | 108 | | | | | | | | | U | 44 | 115 |
| | 25 | 104 | | | | | | | | | U | 100 | 80 |
| | 27 | 102 | | | DS/CD | 10500 | 7320 | | | | U<br>SPT | 100<br>100 | 70/4"<br>105/4' |
| | 24 | 107 | | | | | | | | | U<br>SPT | 100<br>100 | 25/2"<br>100/4" |
| | 18 | 114 | | | | | | | | | U<br>SPT | 100<br>100 | 60/4"<br>100/3' |
| | 22 | 106 | | | | | | | | | U<br>SPT | 75<br>100 | 30/2"<br>150/5" |
| | 23 | 103 | | | | | | | | | U<br>SPT | 100<br>100 | 30/2"<br>114/6" |
| | 26 | 101 | | | | | | | | | U<br>SPT | 80<br>100 | 100/5"<br>100/3" |
| | | | | | | | | | | 9 | GRAB | | |
| | | | | | | | | | | 7<br>12 | NX | 42 | |
| | | | | | | | | | | 18<br>24<br>14 | NX | 49 | |
| | | | | | | | | | | 10<br>18 | PT | 40 | |



ELEVATION +133'

2' OF ASPHALT, 5" OF CONCRETE, 2" CRUSHED ROCK

SP BROWN FINE SAND (DENSE)
(DUNE SAND)

(GRADING VERY DENSE)

WATER LEVEL 2/15/78 6/8/78)

SM DARK GREEN SILTY FINE SAND (VERY DENSE)
(COLMA FOUNDATION)

SP ORANGE BROWN FINE SAND WITH TRACE OF SILT
(VERY DENSE)

(GRADING REDDISH-BROWN, SLIGHTLY MORE SILTY)

(GRADING LESS SILTY)

SC REDDISH-BROWN CLAYEY FINE SAND (DENSE

SP REDDISH-BROWN SLIGHTLY SILTY FINE SAND
(VERY DENSE)

(GRADING LESS SILTY)

SC REDDISH-BROWN CLAYEY FINE SAND (VERY DENSE)

SM REDDISH-BROWN SILTY FINE SAND (VERY DENSE)

(GRADING LESS SILTY)

SP DARK BROWN FINE SAND WITH TRACE OF SILT
(VERY DENSE)

(SILT GRADING OUT)

(GRADING WITH SOME IRON OXIDE STAINING

BLUE-GREEN SERPENTINE ROCK, HIGHLY WEATHERED,
(MEDIUM STRONG)

NOTES
1. SAMPLING RESISTANCE:
SPT DRIVEN BY 140# HAMMER FALLING 30"
U AND TW DRIVEN BY 340# SLIPJARS FALLING 18"
2. ELEVATION REFER TO SF DATUM AND ARE BASED
ON OFFICIAL CITY GRADE

# LOG OF BORING

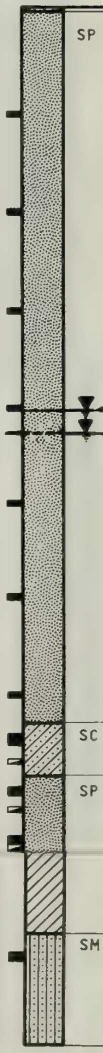
DAMES & MOORE

PLATE A-1K

| Elevation | Other Tests & Information | Moisture Content (%) | Dry Density (PCF) | Atterberg Limits: Liquid Limit | Atterberg Limits: Plastic Limit | Shear Strength Test Results, Laboratory: Type of Test | Shear Strength Test Results, Laboratory: Normal or Confining Pressure (PSF) | Shear Strength Test Results, Laboratory: Peak Shear Strength (PSF) | Shear Strength Test Results, Field: Torvane (PSF) | Shear Strength Test Results, Field: Penetrometer (PSF) | Coring Rate (MIN./FT.) | Sampler Type | Sampler Recovery (%) | Sampling Resistance (BLOWS/FT)or(HYD.PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| +150 | | | | | | | | | | | | | | |
| +140 | | | | | | | | | | | | | | |
| +130 | | 12 | 98 | | | | | | | | | U | 67 | 10 |
| +120 | SA (1%) | | | | | | | | | | | U | 67 | 12 |
| +110 | | 16 | 108 | | | | | | | | | U | 67 | 59 |
| +100 | | 17 | 99 | | | | | | | | | U | 72 | 63 |
| +90 | | 19 | 104 | | | | | | | | | U | 67 | 68 |
| +80 | | 21 | 108 | | | | | | | | | U | 78 | 72 |
| +70 | SA (1%) | 21 | 110 | | | | | | | | | U | 82 | 85/11" |
| | SA (32%) | 12 | 114 | | | | | | | | | U | 78 | 34 |
| | | 12 | | | | | | | | | | SPT | 100 | 49 |
| +60 | | 22 | 107 | | | | DS/CD | 7500 | 6000 | | | U | 75 | 59 |
| | | 23 | | | | | | | | | | SPT | 56 | 30 |
| | | 21 | 108 | | | | | | | | | U | 75 | 80 |
| -90 | | | | | | | | | | | | | | |
| -100 | | 30<br>18 | 97<br>107 | | | | | | | | | TW | 93 | 97/9" |
| -110 | | | | | | | | | | | | | | |

## BORING 12

DRILLED 12/28/77-1/3/78



ELEVATION +141.5'

SANDY RIDING TRAIL

SP BROWN TO YELLOW FINE SAND (LOOSE TO MEDIUM DENSE) (DUNE SAND)

(GRADING TO VERY DENSE)

(WATER LEVEL 2/15/78)

(WATER LEVEL 6/9/78)

SC BROWN CLAYEY FINE SAND (DENSE) (COLMA FORMATION)

SP DARK BROWN TO YELLOW-BROWN FINE SAND (DENSE TO VERY DENSE)

(GRADING TO VERY DENSE, WITH IRON OXIDE

SM GRAY SILTY FINE SAND WITH OCCASIONAL THIN LENSE OF BLACK SILTY CLAY (VERY DENSE)

NOTES:

1. SAMPLING RESISTANCE:
   SPT DRIVEN BY 140# HAMMER FALLING 30"
   U AND TW DRIVEN BY 275# SLIPJARS FALLING 30"
2. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED ON OFFICAL CITY GRADE

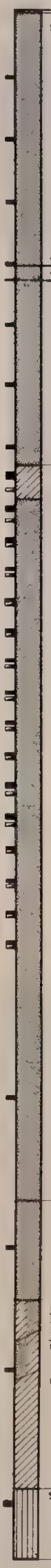
# LOG OF BORING

DAMES & MOORE

# BORING 12

DRILLED 12/28/77-1/3/78

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS | | SHEAR STRENGTH TEST RESULTS | | | | | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD.PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | LIQUID LIMIT | PLASTIC LIMIT | LABORATORY: TYPE OF TEST | LABORATORY: NORMAL OR CONFINING PRESSURE (PSF) | LABORATORY: PEAK SHEAR STRENGTH (PSF) | FIELD: TORVANE (PSF) | FIELD: PENETROMETER (PSF) | | | | |
| +150 | | | | | | | | | | | | | | |
| +140 | | | | | | | | | | | | | | |
| +130 | | 12 | 98 | | | | | | | | | U | 67 | 10 |
| +120 | SA (1%) | | | | | | | | | | | U | 67 | 12 |
| +110 | | 16 | 108 | | | | | | | | | U | 67 | 59 |
| +100 | | 17 | 99 | | | | | | | | | U | 72 | 63 |
| +90 | | 19 | 104 | | | | | | | | | U | 67 | 68 |
| +80 | | 21 | 108 | | | | | | | | | U | 78 | 72 |
| +70 | SA (1%) | 21 | 110 | | | | | | | | | U | 82 | 85/11" |
| | SA (32%) | 12 | 114 | | | | | | | | | U | 78 | 34 |
| | | 12 | | | | | | | | | | SPT | 100 | 49 |
| +60 | | 22 | 107 | | | DS/CD | 7500 | 6000 | | | | U | 75 | 59 |
| | | 23 | | | | | | | | | | SPT | 56 | 30 |
| | | 21 | 108 | | | | | | | | | U | 75 | 80 |
| | | 22 | | | | | | | | | | SPT | 100 | 57/6" |
| | | 22 | 106 | | | | | | | | | U | 83 | 50/6" |
| +50 | | | | | | | | | | | | SPT | 78 | 50/3" |
| | | 21 | 110 | | | | | | | | | U | 75 | 58/6" |
| | | | | | | | | | | | | SPT | 83 | 95/6" |
| | | 20 | 107 | | | | | | | | | U | 67 | 50/3" |
| +40 | | | | | | | | | | | | SPT | 67 | 100/6' |
| | | 22 | 102 | | | DS/CD | 9200 | 6540 | | | | U | 80 | 50/4" |
| | | | | | | | | | | | | SPT | 100 | 50/2" |
| | | 19 | 110 | | | | | | | | | U | 80 | 50/4" |
| +30 | | | | | | | | | | | | SPT | 83 | 96/6" |
| | | 21 | 107 | | | DS/CD | 9900 | 7500 | | | | U | 89 | 50/3" |
| | | | | | | | | | | | | SPT | 100 | 50/2" |
| | PERM SA (1%) | 19 | 108 | | | | | | | | | U | 74 | 50/4" |
| +20 | | | | | | | | | | | | SPT | 83 | 70/6" |
| | | [illegible]1 | 101 | | | | | | | | | U | 91 | 60/5" |
| | | | | | | | | | | | | SPT | 100 | 60/6" |
| | SA (3%) | 23 | 99 | | | | | | | | | U | 92 | 53/6" |
| +10 | | | | | | | | | | | | SPT | 83 | 100/6" |
| | | | | | | | | | | | | U | 40 | 50/4" |
| | | | | | | | | | | | | SPT | 50 | 50/2" |
| | | 23 | 100 | | | | | | | | | U | 83 | 50/6" |
| 0 | | | | | | | | | | | | SPT | 60 | 50/4" |
| | | 22 | 105 | | | | | | | | | U | 73 | 50/5" |
| | | | | | | | | | | | | SPT | 83 | 50/6" |
| | | 20 | 107 | | | | | | | | | U | 80 | 50/4" |
| -10 | | | | | | | | | | | | SPT | 100 | 52/6" |
| -20 | | | | | | | | | | | | | | |
| -30 | | | | | | | | | | | | | | |
| | SA (5%) | 21 | 106 | | | | | | | | | U | 82 | 50/5" |
| -40 | | | | | | | | | | | | | | |
| -50 | | | | | | | | | | | | | | |
| | | 23 | 106 | | | | | | | | | U | 80 | 50/4" |
| -60 | | | | | | | | | | | | | | |
| -70 | | | | | | | | | | | | | | |
| | | 21 | 107 | | | | | | | | | U | 88 | 50/2" |
| -80 | | | | | | | | | | | | | | |
| -90 | | | | | | | | | | | | | | |
| | | 30<br>18 | 97<br>107 | | | | | | | | | TW | 93 | 97/9" |
| -100 | | | | | | | | | | | | | | |
| -110 | | | | | | | | | | | | | | |



ELEVATION +141.5'

SANDY RIDING TRAIL

SP BROWN TO YELLOW FINE SAND (LOOSE TO MEDIUM DENSE) (DUNE SAND)

(GRADING TO VER DENSE)

(WATER LEVEL 2/15/78)

(WATER LEVEL 6/9/78)

SC BROWN CLA E FINE SAND (DENSE) (COLMA FORMATION)

SP DARK BROWN TO YELLOW-BROWN FINE SAND (DENSE TO VERY DENSE)

(GRADING TO VERY DENSE, WITH IRON OXIDE STAINING)

(GRADING MEDIUM GRAINED)

(OCCASIONAL TRACE OF SILT)

SP GREENISH GRAY FINE SAND WITH IRON OXIDE STAINING, OCCASIONAL THIN LENSE OF BLACK CLAY (VERY DENSE)

(CLAY GRADING OUT)

CL/SP DARK GRAY TO GREENISH-GRAY SILTY CLAY WITH FREQUENT LAYERS OF DARK GREEN-GRAY FINE SAND

SP/CL (GRADING MORE SANDY)

CL (GRADING WITH FEWER SAND LAYERS)

SM GRAY SILTY FINE SAND WITH OCCASIONAL THIN LENSE OF BLACK SILTY CLAY (VERY DENSE)

NOTES:

1. SAMPLING RESISTANCE.
   SPT DRIVEN BY 140# HAMMER FALLING 30"
   U AND TW DRIVEN BY 275# SLIPJARS FALLING 30"
2. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED ON OFFICAL CITY GRADE

## LOG OF BORING

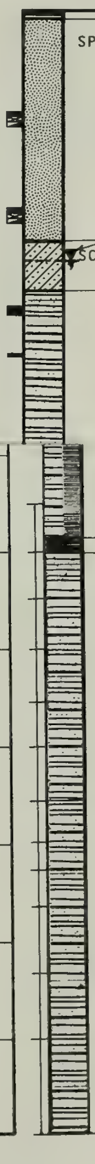
**DAMES & MOORE**

PLATE A-IL

## BORING 13

DRILLED 1/3-17/78

| | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS | | SHEAR STRENGTH TEST RESULTS | | | | | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD. PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | LABORATORY | | | FIELD | | | | | |
| | | | | LIQUID LIMIT | PLASTIC LIMIT | TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | TORVANE (PSF) | PENETROMETER (PSF) | | | | |
| +360 | | | | | | | | | | | | | | |
| +350 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | TW<br>SPT | 67<br>33 | 25<br>37 |
| +340 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | TW<br>SPT | 67<br>67 | 47<br>66 |
| +330 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | U | 56 | 89 |
| | | | | | | | | | | | AVG. | U | 80 | 100<br>5" |
| +320 | | | | | | | | | | | | | | |
| +70 | | | | | | | | | | | | | | |
| | | | | | | | | | | | 7<br>8<br>9<br>10<br>11 | NX | 90 | |
| +60 | | | | | | | | | | | | | | |
| | | | | | | | | | | | 9<br>10<br>[illegible]<br>15<br>26 | NX | 100 | |
| | | | | | | | | | | | 11<br>12<br>14<br>12<br>13 | NX | 96 | |
| +50 | | | | | | | | | | | | | | |
| | | | | | | | | | | | 12<br>12<br>13<br>11<br>16 | NX | 98 | |
| | | | | | | | | | | | 11<br>12<br>10<br>12<br>10 | NX | 100 | |
| +40 | | | | | | | | | | | | | | |
| | | | | | | | | | | | 11<br>15<br>13<br>12<br>12 | NX | 98 | |
| | | | | | | | | | | | 10<br>11<br>12<br>17 | NX | 100 | |
| +30 | | | | | | | | | | | | | | |
| | | | | | | | | | | | [illegible]<br>10 | NX | 98 | |
| | | | | | | | | | | | 12<br>10<br>12<br>[illegible] | NX | 97 | |
| | | | | | | | | | | | 11<br>13<br>13<br>13 | NX | 86 | |
| +20 | | | | | | | | | | | | | | |
| | | | | | | | | | | | 13<br>17<br>28<br>15<br>16<br>15<br>14<br>15<br>13 | NX | 100 | |
| +10 | | | | | | | | | | | | | | |
| | | | | | | | | | | | 14<br>19<br>19<br>14<br>13<br>12<br>12<br>13<br>13<br>25<br>15 | NX | 100 | |



ELEVATION +359.5'

3" OF ASPHALT, 3" OF CRUSHED ROCK FILL

SP — BROWN FINE SAND (MEDIUM DENSE) (DUNE SAND)

(GRADING DENSE)

(GRADING VERY DENSE)

(UPPER WATER LEVEL 2/15/78)

SC — BROWN CLAYEY SAND WITH SANDSTONE FRAGMENTS (VERY DENSE) (COLLUVIUM)

DARK BROWN TO YELLOW-BROWN SANDSTONE, HIGHLY WEATHERED AND FRACTURED, WITH SOME STIFF YELLOW CLAY

(BECOMING LESS WEATHERED, GRAY, FRIABLE, HARD)

GRAY SANDSTONE, FRIABLE

BLACK SHALE, SHEAR ZONE, HIGH SUSCEPTIBILITY TO SLAKING

GRAY GRAYWACKE THICK BEDDED, FRESH, STRONG

(FAULT, BLACK CLAY)

(OCCASIONAL SLICKENSIDED SHALE LAMINATION)

(SHEAR ZONE)

(SHEAR ZONE)

NOTES:

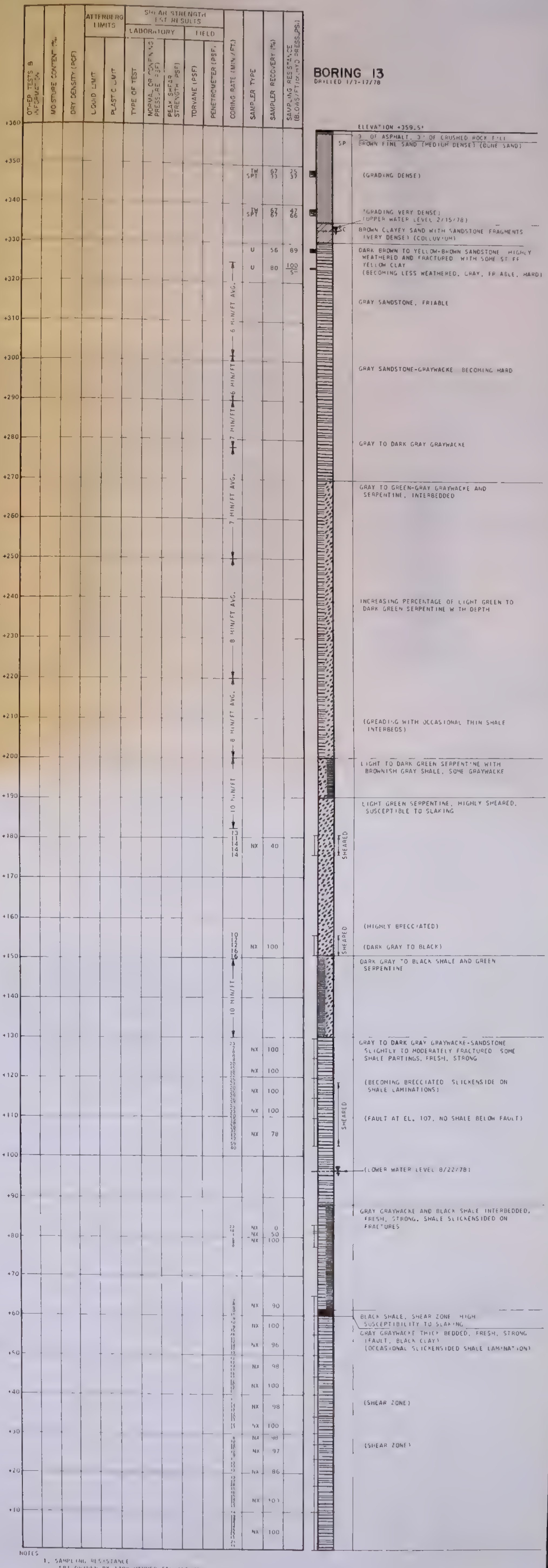
1. SAMPLING RESISTANCE:
   SPT DRIVEN BY 140# HAMMER FALLING 30"
   U AND TW DRIVEN BY 320# SLIPJARS FALLING 14"
2. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED ON PARK DEPARTMENT RECORDS.
3. SEE FOLLOWING GEOLOGIC LOGS FOR A MORE DETAILED DESCRIPTION OF THE BEDROCK.

# LOG OF BORING

**DAMES & MOORE**

# BORING 13

DRILLED 1/3-17/78


OTHER TESTS & INFORMATION
MOISTURE CONTENT (%)
DRY DENSITY (PCF)
ATTERBERG LIMITS
LIQUID LIMIT
PLASTIC LIMIT
SHEAR STRENGTH TEST RESULTS
LABORATORY
TYPE OF TEST
NORMAL OR CONFINING PRESSURE (PSF)
PEAK SHEAR STRENGTH (PSF)
FIELD
TORVANE (PSF)
PENETROMETER (PSF)
CORING RATE (MIN./FT.)
SAMPLER TYPE
SAMPLER RECOVERY (%)
SAMPLING RESISTANCE (BLOWS/FT(or)HYD PRESS,PSI)
ELEVATION IN FEET
+360
+350
+340
+330
+320
+310
+300
+290
+280
+270
+260
+250
+240
+230
+220
+210
+200
+190
+180
+170
+160
+150
+140
+130
+120
+110
+100
+90
+80
+70
+60
+50
+40
+30
+20
+10
6 MIN/FT AVG.
6 MIN/FT
7 MIN/FT
7 MIN/FT AVG.
8 MIN/FT AVG.
8 MIN/FT AVG.
10 MIN/FT
10 MIN/FT
TW SPT 67 33 25 37
TW SPT 67 67 47 66
U 56 89
U 80 100/5"
NX 40
NX 100
NX 100
NX 100
NX 100
NX 100
NX 78
NX 0
NX 50
NX 100
NX 90
NX 100
NX 96
NX 98
NX 100
NX 98
NX 100
NX 98
NX 97
NX 86
NX 101
NX 100
SP
SC
SHEARED
SHEARED
SHEARED
ELEVATION +359.5'
3" OF ASPHALT, 3' OF CRUSHED ROCK FILL
BROWN FINE SAND (MEDIUM DENSE) (DUNE SAND)
(GRADING DENSE)
(GRADING VERY DENSE)
(UPPER WATER LEVEL 2/15/78)
BROWN CLAYEY SAND WITH SANDSTONE FRAGMENTS (VERY DENSE) (COLLUVIUM)
DARK BROWN TO YELLOW-BROWN SANDSTONE HIGHLY WEATHERED AND FRACTURED WITH SOME STIFF YELLOW CLAY
(BECOMING LESS WEATHERED, GRAY, FRIABLE, HARD)
GRAY SANDSTONE, FRIABLE
GRAY SANDSTONE-GRAYWACKE BECOMING HARD
GRAY TO DARK GRAY GRAYWACKE
GRAY TO GREEN-GRAY GRAYWACKE AND SERPENTINE, INTERBEDDED
INCREASING PERCENTAGE OF LIGHT GREEN TO DARK GREEN SERPENTINE WITH DEPTH
(GREADING WITH OCCASIONAL THIN SHALE INTERBEDS)
LIGHT TO DARK GREEN SERPENTINE WITH BROWNISH GRAY SHALE, SOME GRAYWACKE
LIGHT GREEN SERPENTINE, HIGHLY SHEARED, SUSCEPTIBLE TO SLAKING
(HIGHLY BRECCIATED)
(DARK GRAY TO BLACK)
DARK GRAY TO BLACK SHALE AND GREEN SERPENTINE
GRAY TO DARK GRAY GRAYWACKE-SANDSTONE SLIGHTLY TO MODERATELY FRACTURED SOME SHALE PARTINGS, FRESH, STRONG
(BECOMING BRECCIATED SLICKENSIDE ON SHALE LAMINATIONS)
(FAULT AT EL. 107, NO SHALE BELOW FAULT)
(LOWER WATER LEVEL 8/22/78)
GRAY GRAYWACKE AND BLACK SHALE INTERBEDDED, FRESH, STRONG, SHALE SLICKENSIDED ON FRACTURES
BLACK SHALE, SHEAR ZONE HIGH SUSCEPTIBILITY TO SLAKING
GRAY GRAYWACKE THICK BEDDED, FRESH, STRONG
(FAULT, BLACK CLAY)
(OCCASIONAL SLICKENSIDED SHALE LAMINATION)
(SHEAR ZONE)
(SHEAR ZONE)

NOTES

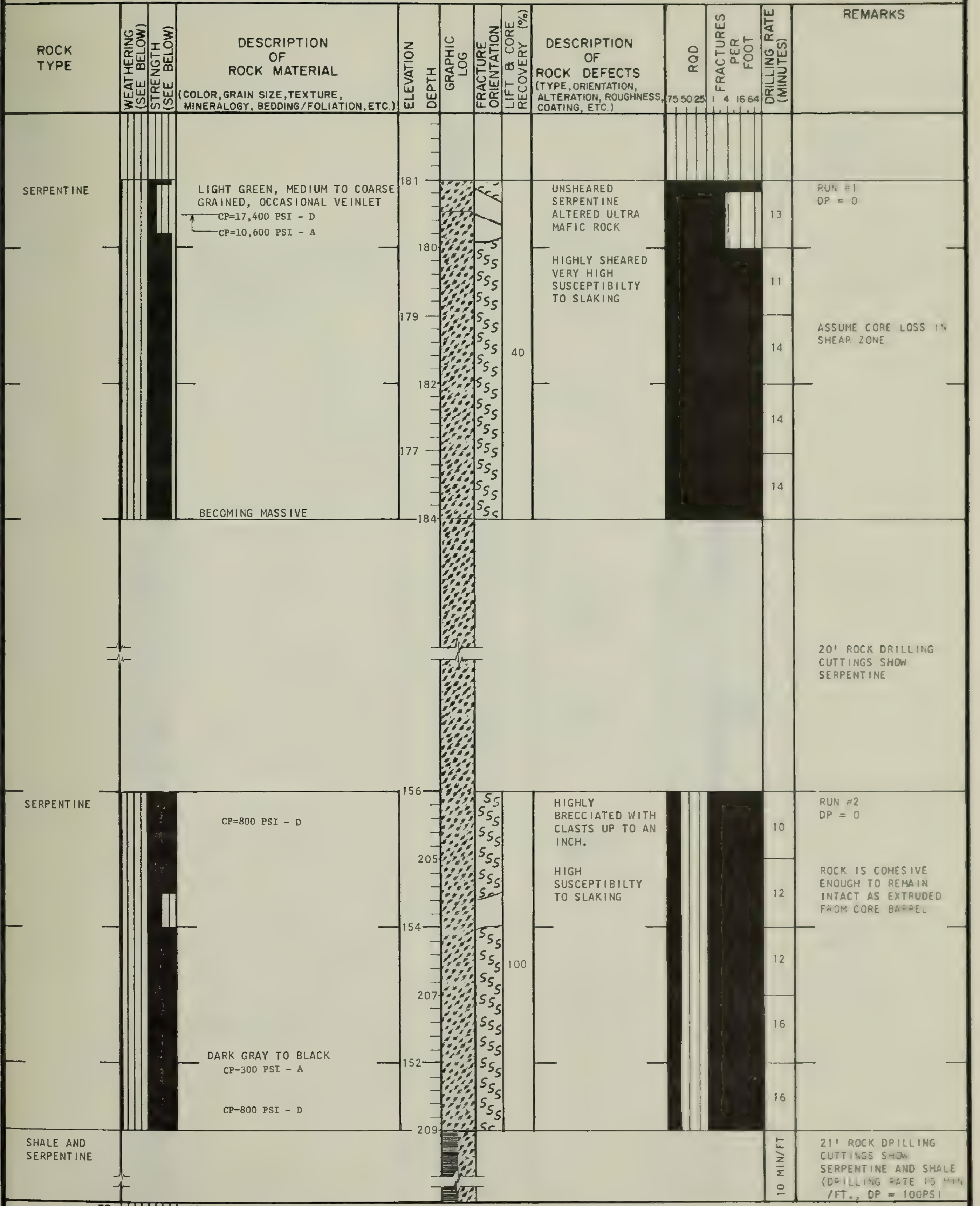
1. SAMPLING RESISTANCE
   SPT DRIVEN BY 140# HAMMER FALLING 30"
   U AND TW DRIVEN BY 320# SLIP JARS FALLING 14"
2. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED ON PARK DEPARTMENT RECORDS
3. SEE FOLLOWING GEOLOGIC LOGS FOR A MORE DETAILED DESCRIPTION OF THE BEDROCK.

## LOG OF BORING

DAMES & MOORE

PLATE A-1M

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 13
PROJECT: RICHMOND TRANSPORT SEWER
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
ANGLE FROM HORIZONTAL 90°
LOCATION PALACE OF LEGION OF HONOR
ELEV. 360
PAGE 1 OF 8



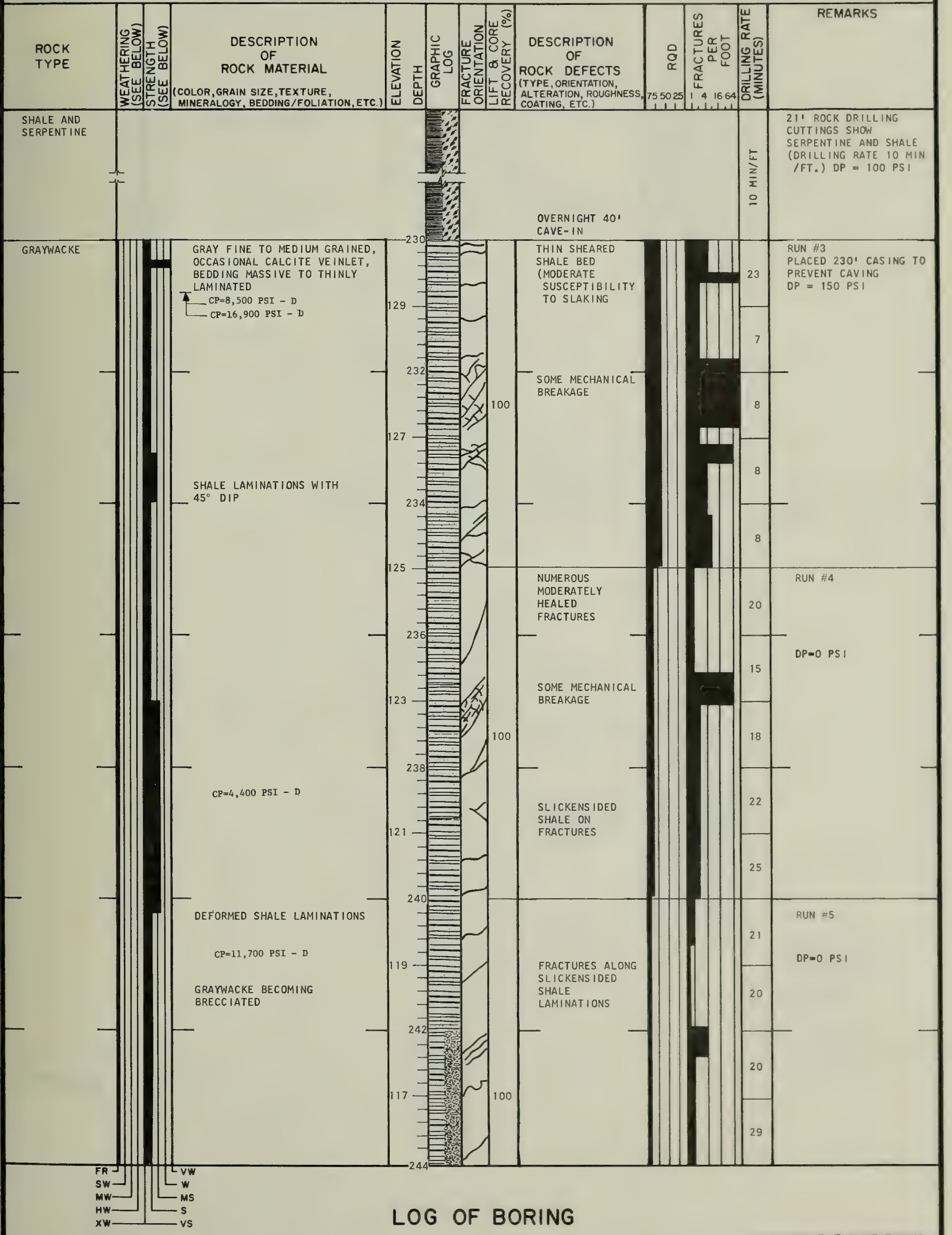
| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|
| SERPENTINE | LIGHT GREEN, MEDIUM TO COARSE GRAINED, OCCASIONAL VEINLET<br>CP=17,400 PSI - D<br>CP=10,600 PSI - A<br>BECOMING MASSIVE | 40 | UNSHEARED SERPENTINE ALTERED ULTRA MAFIC ROCK<br>HIGHLY SHEARED VERY HIGH SUSCEPTIBILTY TO SLAKING | 13<br>11<br>14<br>14<br>14 | RUN #1<br>DP = 0<br>ASSUME CORE LOSS IN SHEAR ZONE |
| | | | | | 20' ROCK DRILLING CUTTINGS SHOW SERPENTINE |
| SERPENTINE | CP=800 PSI - D<br>DARK GRAY TO BLACK<br>CP=300 PSI - A<br>CP=800 PSI - D | 100 | HIGHLY BRECCIATED WITH CLASTS UP TO AN INCH.<br>HIGH SUSCEPTIBILTY TO SLAKING | 10<br>12<br>12<br>16<br>16 | RUN #2<br>DP = 0<br>ROCK IS COHESIVE ENOUGH TO REMAIN INTACT AS EXTRUDED FROM CORE BARREL |
| SHALE AND SERPENTINE | | | | 10 MIN/FT | 21' ROCK DRILLING CUTTINGS SHOW SERPENTINE AND SHALE (DRILLING RATE 10 MIN /FT., DP = 100PSI |

LOG OF BORING

DAMES & MOORE

PLATE A-1M/1

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 13
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION PALACE OF LEGION OF HONOR
ELEV. 360
PAGE 2 OF 8



SHALE AND SERPENTINE

21' ROCK DRILLING CUTTINGS SHOW SERPENTINE AND SHALE (DRILLING RATE 10 MIN /FT.) DP = 100 PSI

OVERNIGHT 40' CAVE-IN

GRAYWACKE

GRAY FINE TO MEDIUM GRAINED, OCCASIONAL CALCITE VEINLET, BEDDING MASSIVE TO THINLY LAMINATED

CP=8,500 PSI - D
CP=16,900 PSI - D

SHALE LAMINATIONS WITH 45° DIP

CP=4,400 PSI - D

DEFORMED SHALE LAMINATIONS

CP=11,700 PSI - D

GRAYWACKE BECOMING BRECCIATED

THIN SHEARED SHALE BED (MODERATE SUSCEPTIBILITY TO SLAKING

SOME MECHANICAL BREAKAGE

NUMEROUS MODERATELY HEALED FRACTURES

SOME MECHANICAL BREAKAGE

SLICKENSIDED SHALE ON FRACTURES

FRACTURES ALONG SLICKENSIDED SHALE LAMINATIONS

RUN #3
PLACED 230' CASING TO PREVENT CAVING
DP = 150 PSI

RUN #4

DP=0 PSI

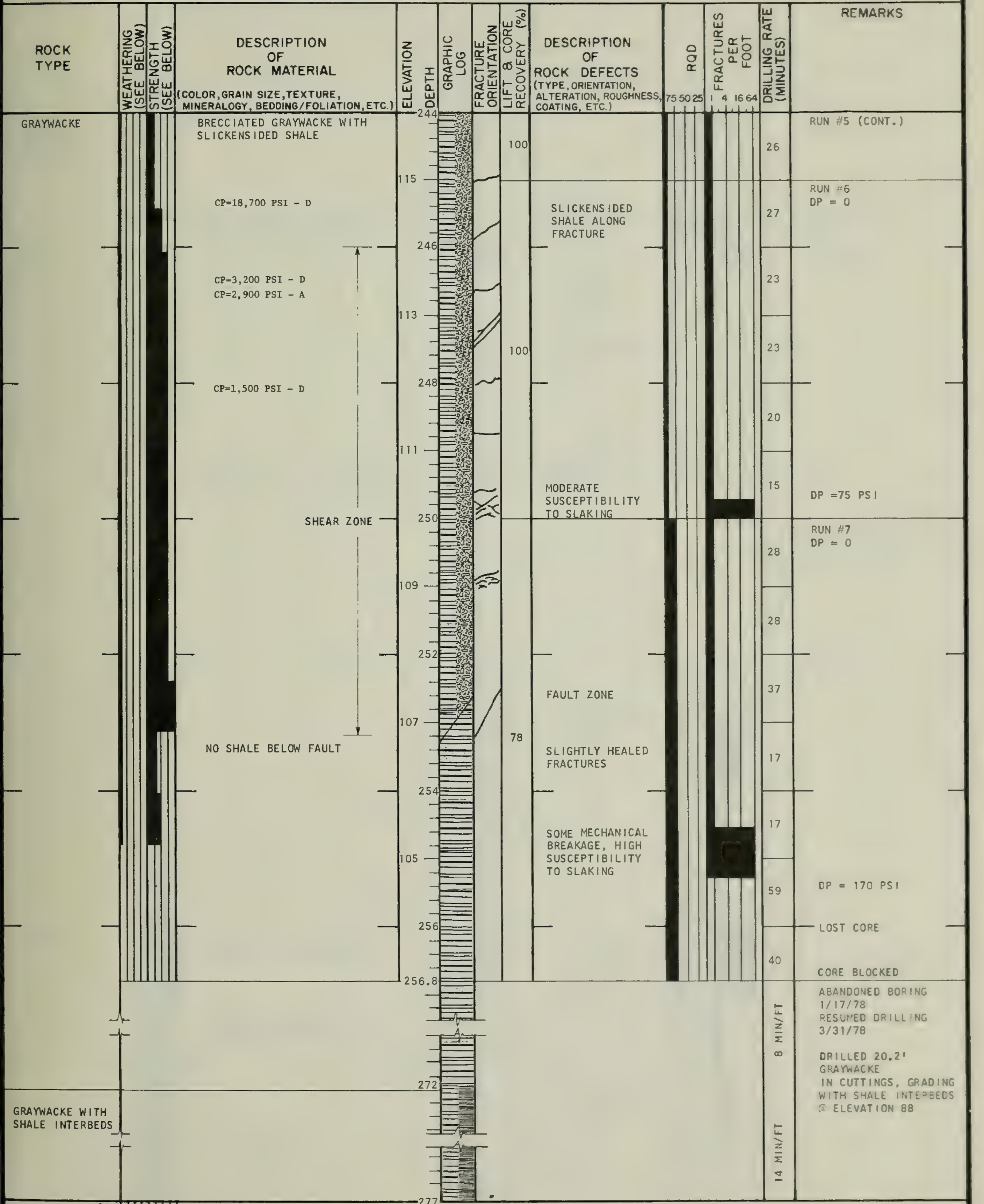
RUN #5

DP=0 PSI

## LOG OF BORING

**DAMES & MOORE**

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 13
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION PALACE OF LEGION OF HONOR
ELEV. 360
PAGE 3 OF 8



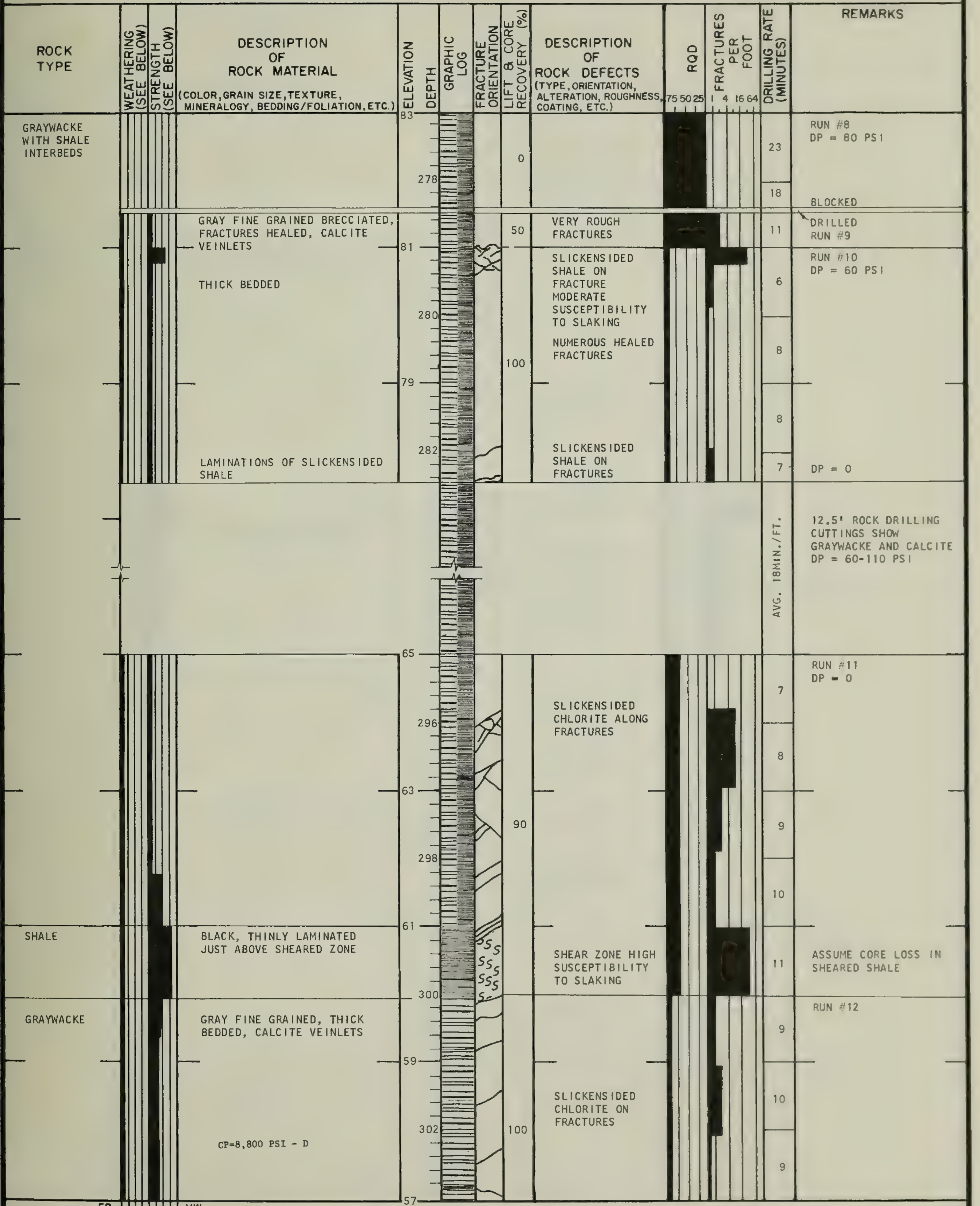
| Depth | Elevation | Rock Type | Description of Rock Material | Lift & Core Recovery (%) | Description of Rock Defects | Drilling Rate (Minutes) | Remarks |
|---|---|---|---|---|---|---|---|
| 244 | | GRAYWACKE | BRECCIATED GRAYWACKE WITH SLICKENSIDED SHALE | 100 | | 26 | RUN #5 (CONT.) |
| | 115 | | CP=18,700 PSI - D | | SLICKENSIDED SHALE ALONG FRACTURE | 27 | RUN #6<br>DP = 0 |
| 246 | | | CP=3,200 PSI - D<br>CP=2,900 PSI - A | | | 23 | |
| | 113 | | | 100 | | 23 | |
| 248 | | | CP=1,500 PSI - D | | | 20 | |
| | 111 | | | | MODERATE SUSCEPTIBILITY TO SLAKING | 15 | DP =75 PSI |
| 250 | | | SHEAR ZONE | | | 28 | RUN #7<br>DP = 0 |
| | 109 | | | | | 28 | |
| 252 | | | | | FAULT ZONE | 37 | |
| | 107 | | NO SHALE BELOW FAULT | 78 | SLIGHTLY HEALED FRACTURES | 17 | |
| 254 | | | | | SOME MECHANICAL BREAKAGE, HIGH SUSCEPTIBILITY TO SLAKING | 17 | |
| | 105 | | | | | 59 | DP = 170 PSI |
| 256 | | | | | | 40 | LOST CORE<br>CORE BLOCKED |
| 256.8 | | | | | | 8 MIN/FT | ABANDONED BORING 1/17/78<br>RESUMED DRILLING 3/31/78<br>DRILLED 20.2' GRAYWACKE IN CUTTINGS, GRADING WITH SHALE INTEPBEDS @ ELEVATION 88 |
| 272 | | GRAYWACKE WITH SHALE INTERBEDS | | | | 14 MIN/FT | |
| 277 | | | | | | | |

FR SW MW HW XW
VW W MS S VS

# LOG OF BORING

DAMES & MOORE

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 13
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX CORING) WITH REVERT SLURRY
LOCATION PALACE OF LEGION OF HONOR
ELEV. 360
PAGE 4 OF 8



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| GRAYWACKE WITH SHALE INTERBEDS | | 83 | 278 | 0 | | 23<br>18 | RUN #8<br>DP = 80 PSI<br>BLOCKED |
| | GRAY FINE GRAINED BRECCIATED, FRACTURES HEALED, CALCITE VEINLETS | | | 50 | VERY ROUGH FRACTURES | 11 | DRILLED RUN #9 |
| | THICK BEDDED<br>LAMINATIONS OF SLICKENSIDED SHALE | 81<br>79 | 280<br>282 | 100 | SLICKENSIDED SHALE ON FRACTURE MODERATE SUSCEPTIBILITY TO SLAKING<br>NUMEROUS HEALED FRACTURES<br>SLICKENSIDED SHALE ON FRACTURES | 6<br>8<br>8<br>7 | RUN #10<br>DP = 60 PSI<br>DP = 0 |
| | | | | | | AVG. 18MIN./FT. | 12.5' ROCK DRILLING CUTTINGS SHOW GRAYWACKE AND CALCITE<br>DP = 60-110 PSI |
| | | 65<br>63 | 296<br>298 | 90 | SLICKENSIDED CHLORITE ALONG FRACTURES | 7<br>8<br>9<br>10 | RUN #11<br>DP = 0 |
| SHALE | BLACK, THINLY LAMINATED JUST ABOVE SHEARED ZONE | 61 | 300 | | SHEAR ZONE HIGH SUSCEPTIBILITY TO SLAKING | 11 | ASSUME CORE LOSS IN SHEARED SHALE |
| GRAYWACKE | GRAY FINE GRAINED, THICK BEDDED, CALCITE VEINLETS<br>CP=8,800 PSI - D | 59<br>57 | 302 | 100 | SLICKENSIDED CHLORITE ON FRACTURES | 9<br>10<br>9 | RUN #12 |

FR SW MW HW XW
VW W MS S VS

LOG OF BORING

**DAMES & MOORE**

PLATE A-1M/4

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)

BORING NO. 13

PROJECT: RICHMOND TRANSPORT SEWER

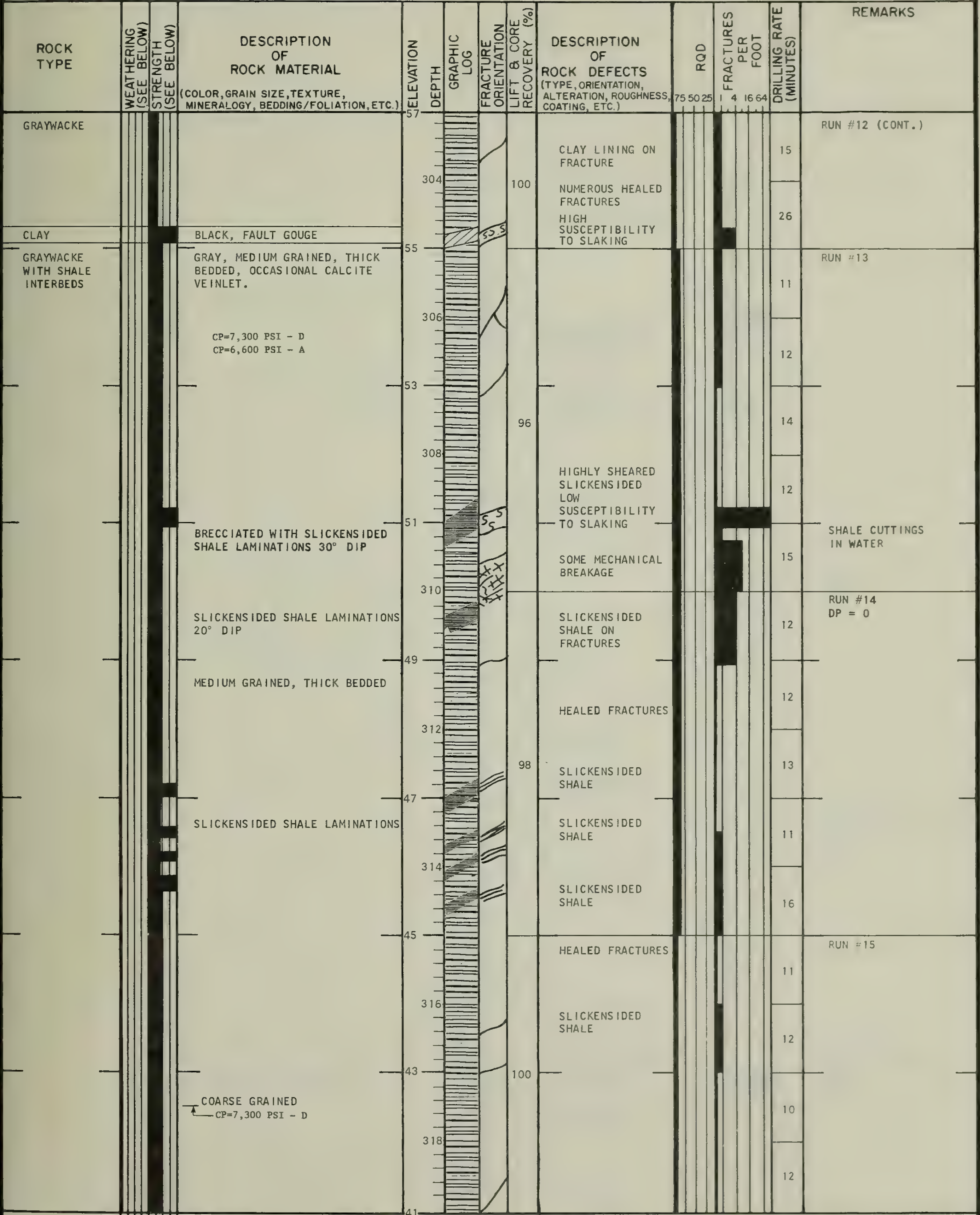
ANGLE FROM HORIZONTAL 90°

DRILLING METHOD: ROTARY WASH (NX CORING) WITH REVERT SLURRY

LOCATION PALACE OF LEGION OF HONOR

ELEV. 360

PAGE 5 OF 8



| DEPTH | ELEVATION | ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| 303–304 | 57 | GRAYWACKE | | 100 | CLAY LINING ON FRACTURE | 15 | RUN #12 (CONT.) |
| 304–305 | | CLAY | BLACK, FAULT GOUGE | | NUMEROUS HEALED FRACTURES<br>HIGH SUSCEPTIBILITY TO SLAKING | 26 | |
| 305–306 | 55 | GRAYWACKE WITH SHALE INTERBEDS | GRAY, MEDIUM GRAINED, THICK BEDDED, OCCASIONAL CALCITE VEINLET. | | | 11 | RUN #13 |
| 306–307 | | | CP=7,300 PSI - D<br>CP=6,600 PSI - A | | | 12 | |
| 307–308 | 53 | | | 96 | | 14 | |
| 308–309 | | | | | HIGHLY SHEARED SLICKENSIDED LOW SUSCEPTIBILITY TO SLAKING | 12 | |
| 309–310 | 51 | | BRECCIATED WITH SLICKENSIDED SHALE LAMINATIONS 30° DIP | | SOME MECHANICAL BREAKAGE | 15 | SHALE CUTTINGS IN WATER |
| 310–311 | | | SLICKENSIDED SHALE LAMINATIONS 20° DIP | | SLICKENSIDED SHALE ON FRACTURES | 12 | RUN #14<br>DP = 0 |
| 311–312 | 49 | | MEDIUM GRAINED, THICK BEDDED | | HEALED FRACTURES | 12 | |
| 312–313 | | | | 98 | SLICKENSIDED SHALE | 13 | |
| 313–314 | 47 | | SLICKENSIDED SHALE LAMINATIONS | | SLICKENSIDED SHALE | 11 | |
| 314–315 | | | | | SLICKENSIDED SHALE | 16 | |
| 315–316 | 45 | | | | HEALED FRACTURES | 11 | RUN #15 |
| 316–317 | | | | | SLICKENSIDED SHALE | 12 | |
| 317–318 | 43 | | COARSE GRAINED<br>CP=7,300 PSI - D | 100 | | 10 | |
| 318–319 | 41 | | | | | 12 | |

| WEATHERING | STRENGTH |
|---|---|
| FR | VW |
| SW | W |
| MW | MS |
| HW | S |
| XW | VS |

## LOG OF BORING

**DAMES & MOORE**

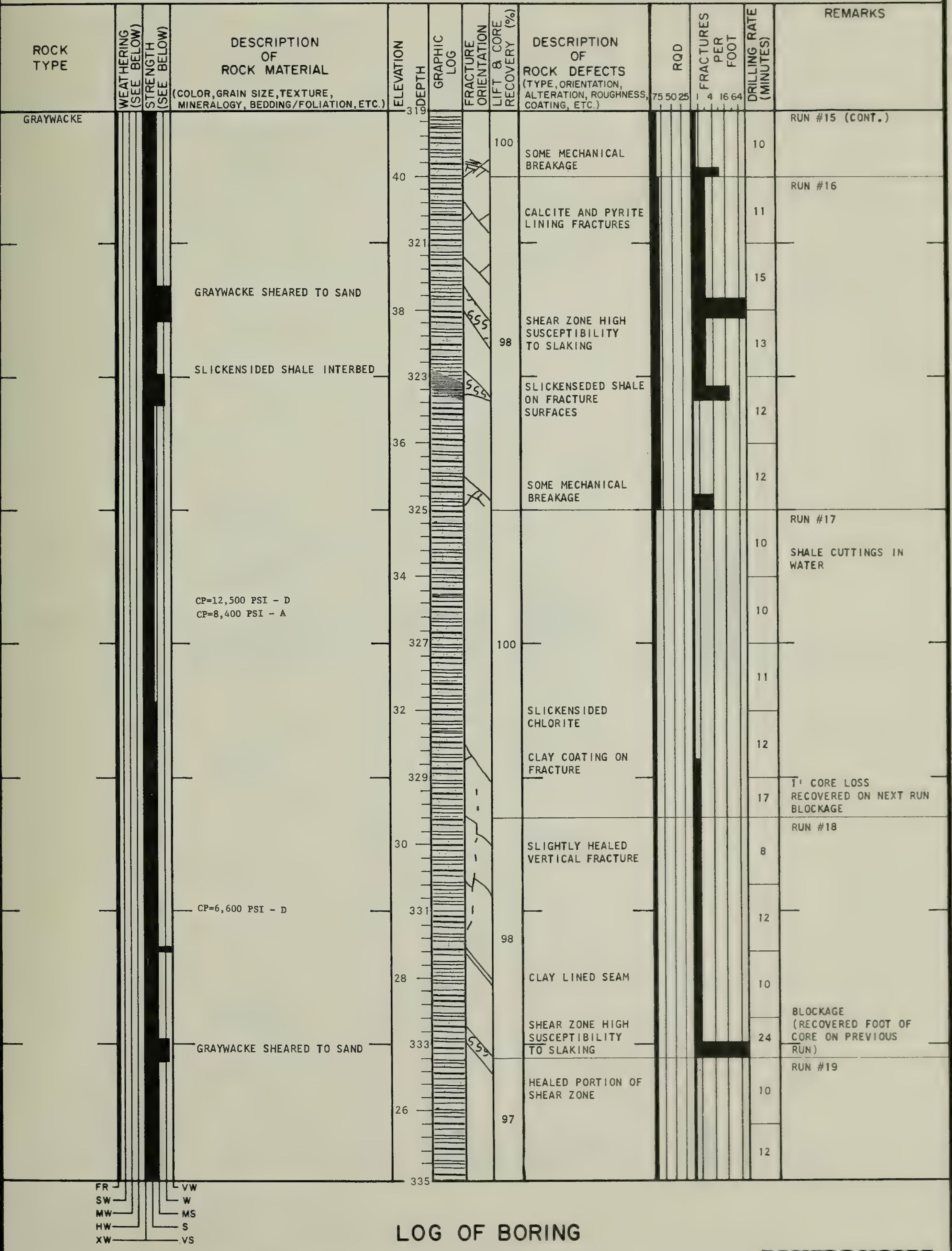
CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03) BORING NO. 13

PROJECT: RICHMOND TRANSPORT SEWER

DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY

ANGLE FROM HORIZONTAL 90°

LOCATION PALACE OF LEGION OF HONOR ELEV. 360 PAGE 6 OF 8



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| GRAYWACKE | | | 319 | 100 | SOME MECHANICAL BREAKAGE | 10 | RUN #15 (CONT.) |
| | | 40 | | | CALCITE AND PYRITE LINING FRACTURES | 11 | RUN #16 |
| | GRAYWACKE SHEARED TO SAND | | 321 | | | 15 | |
| | SLICKENSIDED SHALE INTERBED | 38 | | 98 | SHEAR ZONE HIGH SUSCEPTIBILITY TO SLAKING | 13 | |
| | | | 323 | | SLICKENSEDED SHALE ON FRACTURE SURFACES | 12 | |
| | | 36 | | | SOME MECHANICAL BREAKAGE | 12 | |
| | | | 325 | | | 10 | RUN #17<br>SHALE CUTTINGS IN WATER |
| | CP=12,500 PSI - D<br>CP=8,400 PSI - A | 34 | | | | 10 | |
| | | | 327 | 100 | | 11 | |
| | | 32 | | | SLICKENSIDED CHLORITE<br>CLAY COATING ON FRACTURE | 12 | |
| | | | 329 | | | 17 | 1' CORE LOSS RECOVERED ON NEXT RUN BLOCKAGE |
| | | 30 | | | SLIGHTLY HEALED VERTICAL FRACTURE | 8 | RUN #18 |
| | CP=6,600 PSI - D | | 331 | 98 | | 12 | |
| | | 28 | | | CLAY LINED SEAM | 10 | |
| | GRAYWACKE SHEARED TO SAND | | 333 | | SHEAR ZONE HIGH SUSCEPTIBILITY TO SLAKING | 24 | BLOCKAGE (RECOVERED FOOT OF CORE ON PREVIOUS RUN) |
| | | 26 | | 97 | HEALED PORTION OF SHEAR ZONE | 10 | RUN #19 |
| | | | 335 | | | 12 | |

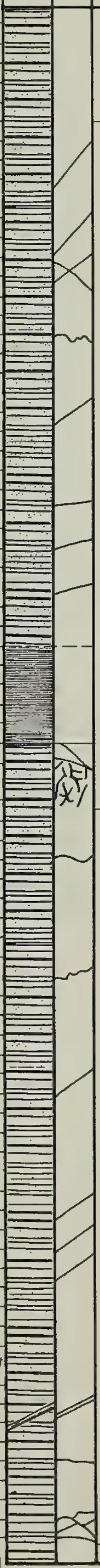
LOG OF BORING

DAMES & MOORE

PLATE A-IM/6

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 13
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION PALACE OF LEGION OF HONOR
ELEV. 360
PAGE 7 OF 8

| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ROUGHNESS, ALTERATION, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| GRAYWACKE | | | 335 | | | 12 | RUN #19 (CONT.) |
| | CP=7,300 PSI - D<br>CP=4,200 PSI - A | | | 97 | | 9 | |
| | | 24 | | | | | |
| | | | | | SOME CLAY, CALCITE AND PYRITE COATING | 11 | RUN #20 |
| | CP=6,100 PSI - D | | 337 | | | | |
| | | | | | SLICKENSIDED CHLORITE CLASTS | 13 | SHALE CUTTINGS IN WATER |
| | | 22 | | | | | |
| | | | | | | 13 | |
| | CP=3,800 PSI - D | | 339 | | | | |
| | | | | 86 | | 13 | |
| | | 20 | | | | | |
| | | | | | | 13 | |
| | CP=5,400 PSI - D<br>CP=1,900 PSI - A | | 341 | | | | |
| SHALE ? | LOSS COULD HAVE BEEN IN 1 FOOT SHALEY UNIT<br>CP=7,700 PSI - D | | | | | 17 | |
| | | 18 | | | | | |
| | | | | | (SHEAR ZONE) MECHANICAL FRACTURES AND SLICKENSIDED SHALE | 28 | |
| GRAYWACKE | GRAY, FINE GRAINED WITH SLICKENSIDED SHALE LAMINATIONS THICK BEDDED SHALE LAMINATIONS GRADING OUT. | | 343 | | | 25 | BLOCKED |
| | | | | | | 15 | RUN #21 |
| | | 16 | | | | | |
| | CP=10,700 PSI - D<br>CP=13,800 PSI - D | | | | | 16 | |
| | | | 345 | | ROUGH | | |
| | | | | | | 15 | |
| | | 14 | | | SLICKENSIDED CHLORITE CLASTS | | |
| | | | | 100 | | 14 | |
| | | | 347 | | | | |
| | | | | | | 15 | |
| | | 12 | | | CLAY COATING | | |
| | CP=10,700 PSI - D<br>CP=8,200 PSI - D | | | | | 13 | |
| | | | 349 | | | | |
| | BEDDING 30° DIP SHALE LAMINATION | | | | | 14 | |
| | | 10 | | | | | |
| | | | | | SOME MECHANICAL BREAKAGE | 15 | |
| | | | 351 | 100 | | 19 | RUN #22 |



WEATHERING (SEE BELOW): FR, SW, MW, HW, XW
STRENGTH (SEE BELOW): VW, W, MS, S, VS
RQD: 75 50 25
FRACTURES PER FOOT: 1 4 16 64

LOG OF BORING

**DAMES & MOORE**

PLATE A-IM/7

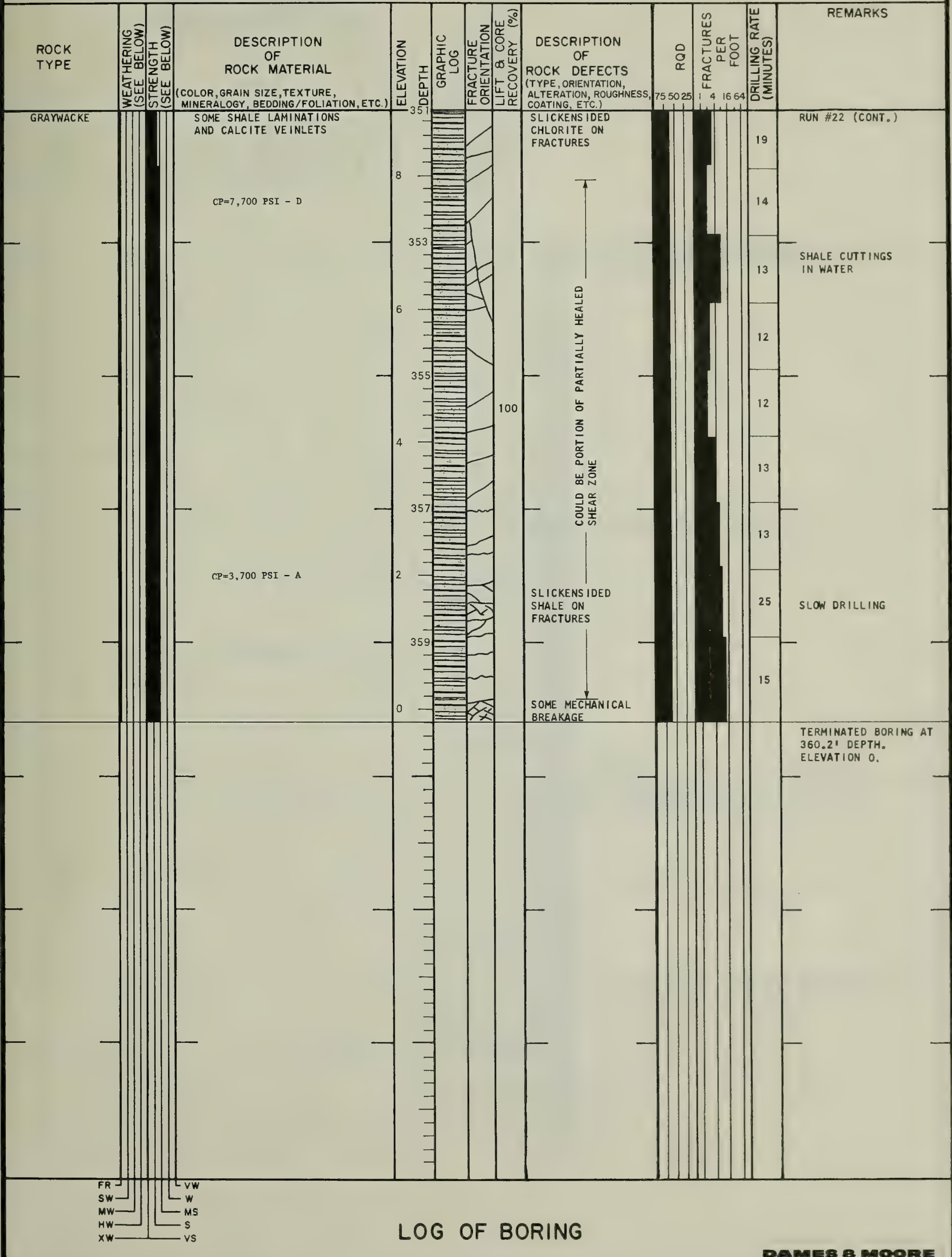
CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03) BORING NO. 13

PROJECT: RICHMOND TRANSPORT SEWER

DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY

ANGLE FROM HORIZONTAL 90°

LOCATION PALACE OF LEGION OF HONOR ELEV. 360 PAGE 8 OF 8



GRAYWACKE

SOME SHALE LAMINATIONS AND CALCITE VEINLETS

CP=7,700 PSI - D

CP=3,700 PSI - A

SLICKENSIDED CHLORITE ON FRACTURES

COULD BE PORTION OF PARTIALLY HEALED SHEAR ZONE

SLICKENSIDED SHALE ON FRACTURES

SOME MECHANICAL BREAKAGE

RUN #22 (CONT.)

SHALE CUTTINGS IN WATER

SLOW DRILLING

TERMINATED BORING AT 360.2' DEPTH. ELEVATION 0.

## LOG OF BORING

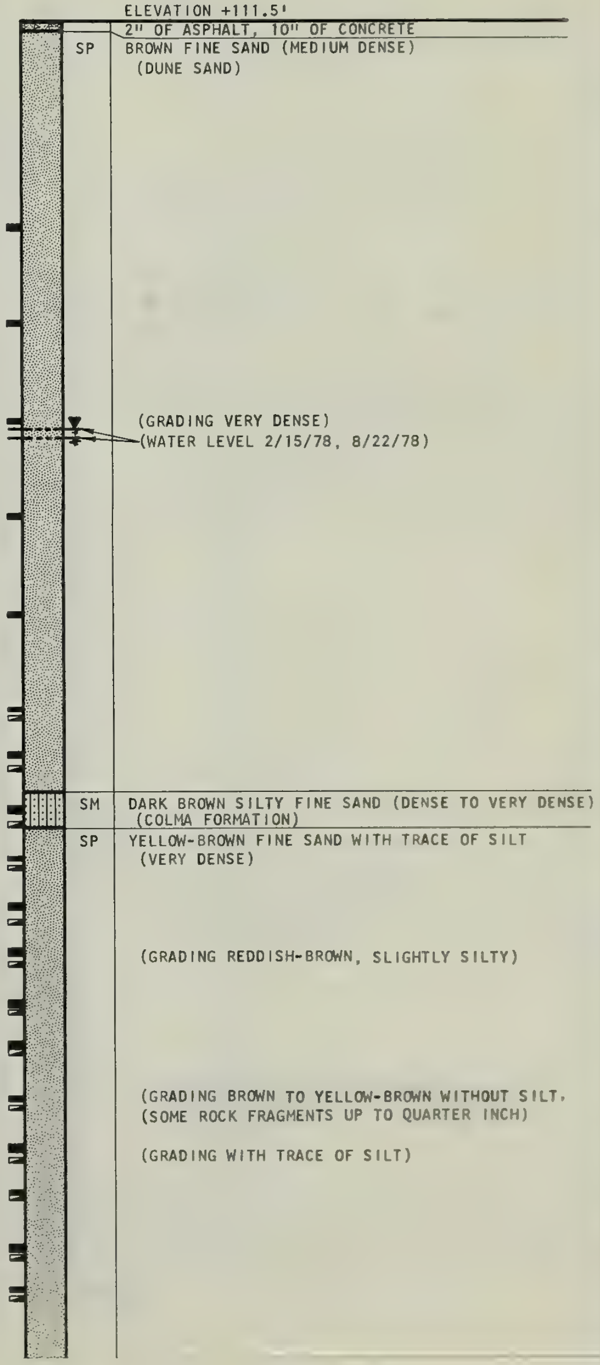
**DAMES & MOORE**

PLATE A-1M/8

# BORING 14

DRILLED 1/3-6/78

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | SHEAR STRENGTH TEST RESULTS, LABORATORY: TYPE OF TEST | LABORATORY: NORMAL OR CONFINING PRESSURE (PSF) | LABORATORY: PEAK SHEAR STRENGTH (PSF) | FIELD: TORVANE (PSF) | FIELD: PENETROMETER (PSF) | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD.PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| +120 | | | | | | | | | | | | | | |
| +110 | | | | | | | | | | | | | | |
| +100 | | | | | | | | | | | | | | |
| +90 | | 11 | 99 | | | | | | | | | U | 72 | 14 |
| +80 | | 13 | 103 | | | | | | | | | U | NR | 28 |
| +70 | | 16 | 110 | | | DS/CD | 4500 | 3580 | | | | U | 72 | 98 |
| +60 | | 18 | 111 | | | | | | | | | U | 79 | 80/8" |
| +50 | | 19 | 109 | | | DS/CD | 6500 | 5160 | | | | U | 84 | 95/10" |
| +40 | | 20 | - | | | | | | | | | U<br>SPT | 75<br>67 | 96/10"<br>71/6" |
| | | 18 | 111 | | | | | | | | | U<br>SPT | 83<br>67 | 50/6"<br>67/9" |
| +30 | | 13<br>11 | 125<br>- | | | DS/CD | 7600 | 5780 | | | | U<br>SPT | 75<br>NR | 33<br>89 |
| | | 16 | 118 | | | | | | | | | U<br>SPT | 75<br>100 | 63<br>50/6" |
| +20 | | 18 | 115 | | | | | | | | | U<br>SPT | 72<br>72 | 86<br>74 |
| | PERM<br>SA<br>(11%) | 19 | 119 | | | | | | | | | U<br>SPT | 78<br>80 | 94/11"<br>94/9" |
| +10 | | 20 | 108 | | | | | | | | | U<br>SPT | 72<br>67 | 75<br>50/3" |
| | | 22 | 114 | | | | | | | | | U<br>SPT | 91<br>67 | 50/5"<br>50/6" |
| 0 | | 20 | 109 | | | | | | | | | U<br>SPT | 78<br>67 | 98/11"<br>50/3" |
| | | 20 | 110 | | | | | | | | | U<br>SPT | 78<br>67 | 76<br>50/6" |
| -10 | | 22 | 107 | | | | | | | | | U<br>SPT | 78<br>100 | 50/5"<br>100/5" |
| | | 22 | 105 | | | | | | | | | U<br>SPT | 75<br>78 | 59<br>50/3" |
| -20 | | 21 | 109 | | | | | | | | | U<br>SPT | 89 | 50/3"<br>50/3" |



ELEVATION +111.5'

2" OF ASPHALT, 10" OF CONCRETE

SP BROWN FINE SAND (MEDIUM DENSE)
(DUNE SAND)

(GRADING VERY DENSE)

(WATER LEVEL 2/15/78, 8/22/78)

SM DARK BROWN SILTY FINE SAND (DENSE TO VERY DENSE)
(COLMA FORMATION)

SP YELLOW-BROWN FINE SAND WITH TRACE OF SILT
(VERY DENSE)

(GRADING REDDISH-BROWN, SLIGHTLY SILTY)

(GRADING BROWN TO YELLOW-BROWN WITHOUT SILT.
(SOME ROCK FRAGMENTS UP TO QUARTER INCH)

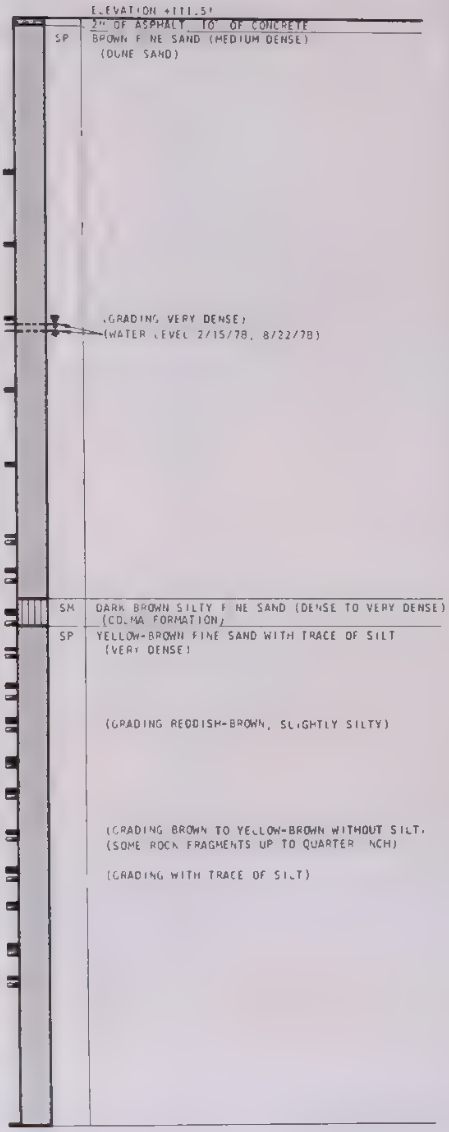
(GRADING WITH TRACE OF SILT)

**DAMES & MOORE**

PLATE A-1N

## BORING 14
DRILLED 1/3-6/78

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | SHEAR STRENGTH TEST RESULTS, LABORATORY: TYPE OF TEST | LABORATORY: NORMAL OR CONFINING PRESSURE (PSF) | LABORATORY: PEAK SHEAR STRENGTH (PSF) | FIELD: TORVANE (PSF) | FIELD: PENETROMETER (PSF) | CORING RATE (MIN/FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT(or HYD PRESS, PSI)) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| +120 | | | | | | | | | | | | | | |
| +110 | | | | | | | | | | | | | | |
| +100 | | | | | | | | | | | | | | |
| +90 | | 11 | 99 | | | | | | | | | U | 72 | 14 |
| +80 | | 13 | 103 | | | | | | | | | U | NR | 28 |
| +70 | | [illegible] | 110 | | | DS/CD | 4500 | 3580 | | | | U | 72 | 98 |
| +60 | | 18 | 111 | | | | | | | | | U | 79 | 80/8" |
| +50 | | 19 | 109 | | | DS/CD | 6500 | 5160 | | | | U | 84 | 95/10" |
| +40 | | 20 | - | | | | | | | | | U<br>SPT | 75<br>67 | 96/10"<br>71/6" |
| | | 18 | 111 | | | | | | | | | U<br>SPT | 83<br>67 | 50/6"<br>67/9" |
| +30 | | 13<br>11 | 125<br>- | | | DS/CD | 7600 | 5780 | | | | U<br>SPT | 75<br>NR | 33<br>89 |
| | | 16 | 118 | | | | | | | | | U<br>SPT | 75<br>100 | 63<br>50/6" |
| +20 | | 18 | 115 | | | | | | | | | U<br>SPT | 72<br>72 | 86<br>74 |
| | PERM<br>CA<br>11 | 19 | 119 | | | | | | | | | U<br>SPT | 78<br>80 | 94/11<br>94/9 |
| +10 | | 20 | 108 | | | | | | | | | U<br>SPT | 72<br>67 | 75<br>50/3" |
| | | 22 | 114 | | | | | | | | | U<br>SPT | 91<br>67 | 50/5"<br>50/6" |
| 0 | | 20 | 109 | | | | | | | | | U<br>SPT | 78<br>67 | 98/11<br>50/3 |
| | | 20 | 110 | | | | | | | | | U<br>SPT | 78<br>67 | 76<br>50/6" |
| -10 | | 22 | 107 | | | | | | | | | U<br>SPT | 78<br>100 | 50/5"<br>100/5" |
| | | 22 | 105 | | | | | | | | | U<br>SPT | 75<br>78 | 59<br>50/3 |
| | | 21 | 109 | | | | | | | | | U<br>SPT | 89 | 50/3"<br>50/3" |
| -20 | | | | | | | | | | | | | | |
| -30 | | | | | | | | | | | | | | |
| -40 | | 17 | 115 | | | | | | | | | U | 88 | 40/2 |



ELEVATION +111.5'

2" OF ASPHALT, 10" OF CONCRETE

SP BROWN FINE SAND (MEDIUM DENSE)
(DUNE SAND)

(GRADING VERY DENSE)
(WATER LEVEL 2/15/78, 8/22/78)

SM DARK BROWN SILTY FINE SAND (DENSE TO VERY DENSE)
(COLMA FORMATION)

SP YELLOW-BROWN FINE SAND WITH TRACE OF SILT
(VERY DENSE)

(GRADING REDDISH-BROWN, SLIGHTLY SILTY)

(GRADING BROWN TO YELLOW-BROWN WITHOUT SILT)
(SOME ROCK FRAGMENTS UP TO QUARTER INCH)

(GRADING WITH TRACE OF SILT)

NOTES

1. SAMPLING RESISTANCE
   SPT DRIVEN BY 140# HAMMER FALLING 30"
   U SAMPLER DRIVEN BY 275# SLUGS FALLING 30"
2. ELEVATIONS REFER TO SF DATUM AND ARE BASED ON OFFICIAL CITY GRADE.

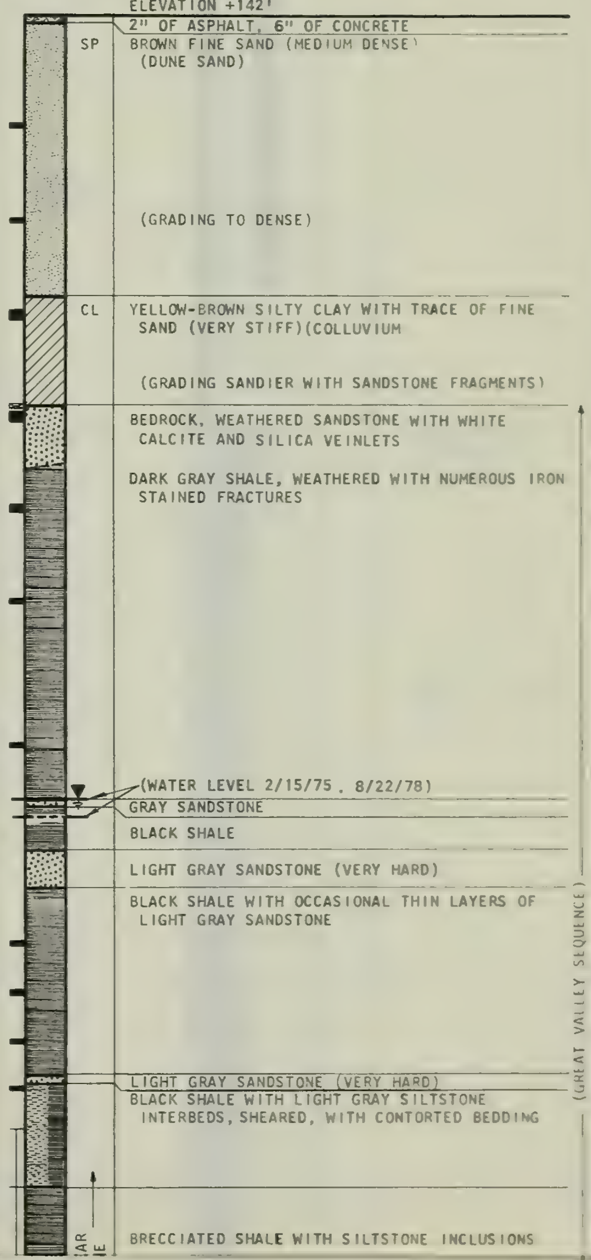
# LOG OF BORING

**DAMES & MOORE**

# BORING 15

DRILLED 1/6-12/78

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS | | SHEAR STRENGTH TEST RESULTS | | | | | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT) or (HYD. PRESS., PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | LABORATORY | | | FIELD | | | | | |
| | | | | LIQUID LIMIT | PLASTIC LIMIT | TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | TORVANE (PSF) | PENETROMETER (PSF) | | | | |
| +150 | | | | | | | | | | | | | | |
| +140 | | | | | | | | | | | | | | |
| +130 | | 16 | 109 | | | | | | | | | U | 75 | 15 |
| +120 | | 13 | 101 | | | | | | | | | U | 75 | 38 |
| +110 | | 22 | 105 | | | | | | | | | TW | 100 | 17 |
| | | | | | | | | | | | | TW | 17 | 86/6" |
| +100 | | 17 | | | | | | | | | | U | 100 | 100/6" |
| +90 | | | | | | | | | | | | U | 100 | 70/6" |
| +80 | | | | | | | | | | | | U | 80 | 50/4" |
| +70 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | U | 83 | 100/6" |
| +60 | | | | | | | | | | | | | | |
| +50 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | U | 67 | 50/3" |
| +40 | | | | | | | | | | | | U | 89 | 50/3" |
| | | | | | | | | | | | | U | 86 | 80/1" |
| +30 | | | | | | | | | | | | U | 67 | 50/6" |
| | | | | | | | | | | | | NX | 77 | |
| +20 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | NX | 3 | |



ELEVATION +142'

2" OF ASPHALT, 6" OF CONCRETE

BROWN FINE SAND (MEDIUM DENSE) (DUNE SAND)

(GRADING TO DENSE)

YELLOW-BROWN SILTY CLAY WITH TRACE OF FINE SAND (VERY STIFF)(COLLUVIUM

(GRADING SANDIER WITH SANDSTONE FRAGMENTS)

BEDROCK, WEATHERED SANDSTONE WITH WHITE CALCITE AND SILICA VEINLETS

DARK GRAY SHALE, WEATHERED WITH NUMEROUS IRON STAINED FRACTURES

(WATER LEVEL 2/15/75 , 8/22/78)

GRAY SANDSTONE

BLACK SHALE

LIGHT GRAY SANDSTONE (VERY HARD)

BLACK SHALE WITH OCCASIONAL THIN LAYERS OF LIGHT GRAY SANDSTONE

LIGHT GRAY SANDSTONE (VERY HARD)

BLACK SHALE WITH LIGHT GRAY SILTSTONE INTERBEDS, SHEARED, WITH CONTORTED BEDDING

BRECCIATED SHALE WITH SILTSTONE INCLUSIONS

## LOG OF BORING

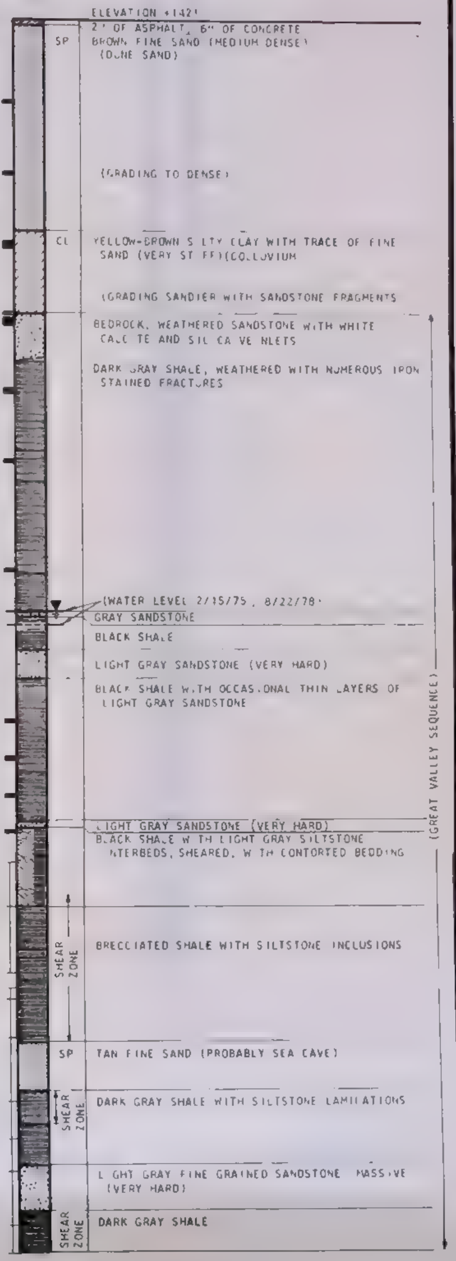
DAMES & MOORE

PLATE A-10

# BORING 15

DRILLED 1/6-12/78

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS | | SHEAR STRENGTH TEST RESULTS | | | | | CORING RATE (MIN/FT) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD PRESS,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | LABORATORY | | | FIELD | | | | | |
| | | | | LIQUID LIMIT | PLASTIC LIMIT | TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | TORVANE (PSF) | PENETROMETER (PSF) | | | | |
| +130 | | 16 | 109 | | | | | | | | | U | 75 | 15 |
| +120 | | 13 | 101 | | | | | | | | | U | 75 | 38 |
| +110 | | 22 | 105 | | | | | | | | | TW | 100 | 17 |
| +100 | | 17 | | | | | | | | | | TW<br>U | 17<br>100 | 86/6"<br>100/6" |
| | | | | | | | | | | | | U | 100 | 70/6 |
| | | | | | | | | | | | | U | 80 | 50/4" |
| | | | | | | | | | | | | U | 83 | 100/6" |
| | | | | | | | | | | | | U | 67 | 50/3" |
| | | | | | | | | | | | | U | 89 | 50/3" |
| | | | | | | | | | | | | U | 86 | 80/1" |
| | | | | | | | | | | | | U | 67 | 50/6" |
| | | | | | | | | | | | | NX | 77 | |
| | | | | | | | | | | | | NX | 3 | |
| | | | | | | | | | | | 6-7 | PT | 95 | |
| | | | | | | | | | | | | NX | 92 | |
| | | | | | | | | | | | 25 | NX | 26 | |
| | | | | | | | | | | | 5 | NX | 27 | |
| | | | | | | | | | | | 4<br>4<br>4<br>20<br>6<br>6 | NX | 90 | |
| | | | | | | | | | | | 6<br>6<br>5<br>5<br>4 | NX | 98 | |
| | | | | | | | | | | | | NX | 62 | |



ELEVATION +142'

2' OF ASPHALT, 6" OF CONCRETE

BROWN FINE SAND (MEDIUM DENSE)
(DUNE SAND)

(GRADING TO DENSE)

YELLOW-BROWN SILTY CLAY WITH TRACE OF FINE SAND (VERY STIFF)(COLLUVIUM

(GRADING SANDIER WITH SANDSTONE FRAGMENTS

BEDROCK, WEATHERED SANDSTONE WITH WHITE CALCITE AND SILICA VEINLETS

DARK GRAY SHALE, WEATHERED WITH NUMEROUS IRON STAINED FRACTURES

(WATER LEVEL 2/15/75, 8/22/78)

GRAY SANDSTONE

BLACK SHALE

LIGHT GRAY SANDSTONE (VERY HARD)

BLACK SHALE WITH OCCASIONAL THIN LAYERS OF LIGHT GRAY SANDSTONE

LIGHT GRAY SANDSTONE (VERY HARD)

BLACK SHALE WITH LIGHT GRAY SILTSTONE INTERBEDS, SHEARED, WITH CONTORTED BEDDING

BRECCIATED SHALE WITH SILTSTONE INCLUSIONS

TAN FINE SAND (PROBABLY SEA CAVE)

DARK GRAY SHALE WITH SILTSTONE LAMINATIONS

LIGHT GRAY FINE GRAINED SANDSTONE MASSIVE (VERY HARD)

DARK GRAY SHALE

NOTES:

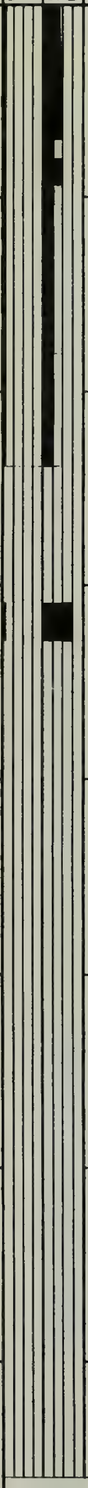
1. SAMPLING RESISTANCE:
   SPT DRIVEN BY 140# HAMMER FALLING 30"
   U AND TW DRIVEN BY 275# SLIPJARS FALLING 30"
2. ELEVATIONS REFER TO SF DATUM AND ARE BASED ON OFFICIAL CITY GRADE
3. REFER TO FOLLOWING GEOLOGIC LOGS FOR A MORE DETAILED DESCRIPTION OF THE BEDROCK.

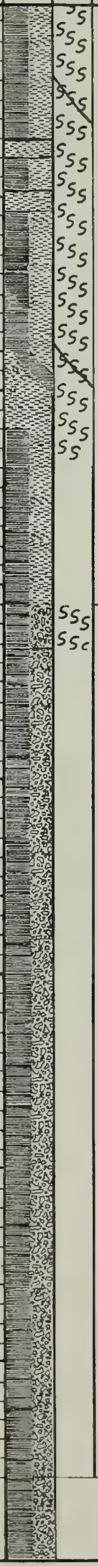
# LOG OF BORING

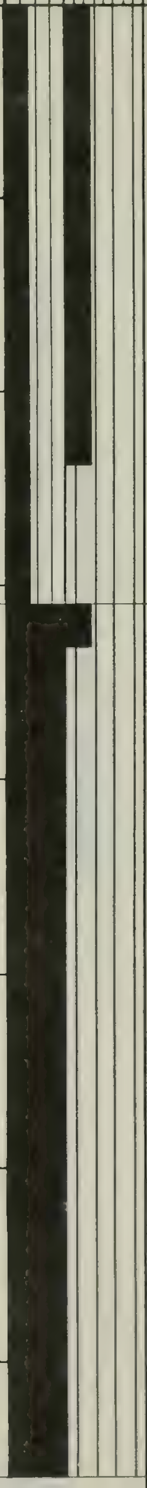
**DAMES & MOORE**

PLATE A-10

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 15
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION SUTRO HEIGHTS NEAR 48th. AVE.
ELEV. 142
PAGE 1 OF 4







| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| SHALE AND SILTSTONE | LAMINATED DARK GRAY SHALE AND LIGHT GRAY SILTSTONE WITH CALCITE VEINLETS, LAMINATIONS GENERALLY CONTORTED | 27 | | | CONTORTED BEDDING | | RUN #1<br>LOST CORE PROBABLY SHALE |
| | LIGHT GRAY SILTSTONE INTERBED | | 116 | | FAULT PLANE | | |
| | SILTSTONE INTERBED<br>CP=19,100 PSI - D | 25 | | | SHALE HAS HIGH SUSCEPTIBILITY TO SLAKING | | |
| | | | 118 | 77 | | | |
| | SILTSTONE INTERBED WITH SHALE INCLUSION<br>CP=14,300 PSI - D<br>CP=14,300 PSI - D | 23 | | | COULD BE BEDDING | | |
| | | | 120 | | | | |
| | BRECCIATED SILTSTONE AND SHALE | 21 | | | SHEAR ZONE | | PEBBLE STUCK IN CORE BARREL<br>RUN #2 |
| | | | 122 | | | | |
| | CUTTINGS SHOW CHIEFLY DARK GRAY SHALE | 19 | | | | | |
| | | | 124 | | | | CHIEFLY DARK GRAY SHALE |
| | | 17 | | | | | |
| | | | 126 | | | | |
| | | 15 | | 3 | | | |
| | | | 128 | | | | |
| | | 13 | | | | | |
| | | | 130 | | | | DRILLED TO 132' WITH TRICONE |
| | | 11 | | | | | |

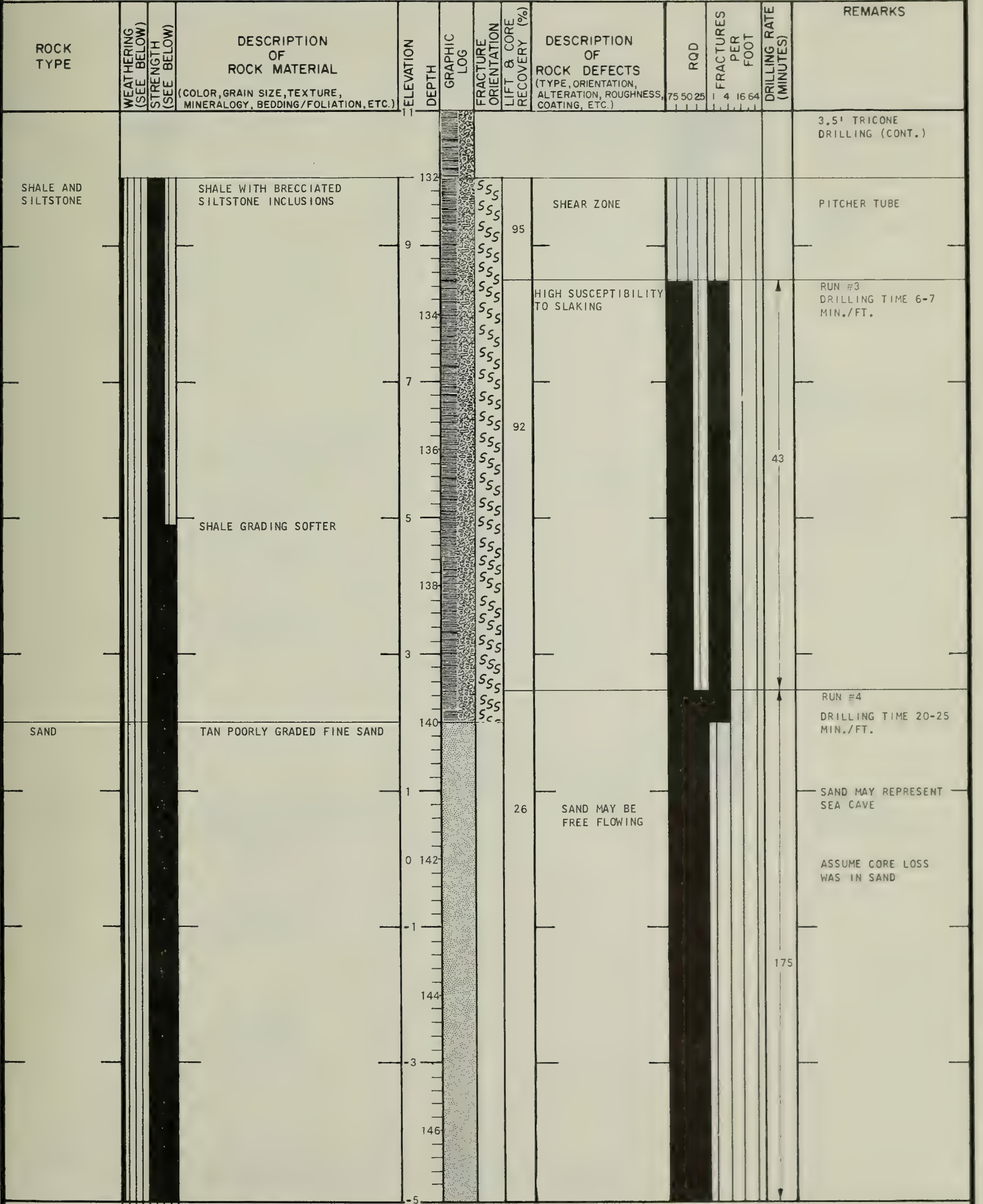
FR, SW, MW, HW, XW
VW, W, MS, S, VS

## LOG OF BORING

DAMES & MOORE

PLATE A-10/1

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 15
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION SUTRO HEIGHTS NEAR 48th. AVE.
ELEV. 142
PAGE 2 OF 4



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|
| | | 131–132 | | | | 3.5' TRICONE DRILLING (CONT.) |
| SHALE AND SILTSTONE | SHALE WITH BRECCIATED SILTSTONE INCLUSIONS | 132 | 95 | SHEAR ZONE | | PITCHER TUBE |
| | | | 92 | HIGH SUSCEPTIBILITY TO SLAKING | 43 | RUN #3<br>DRILLING TIME 6-7 MIN./FT. |
| | SHALE GRADING SOFTER | | | | | |
| | | | | | 175 | RUN #4<br>DRILLING TIME 20-25 MIN./FT. |
| SAND | TAN POORLY GRADED FINE SAND | 140 | 26 | SAND MAY BE FREE FLOWING | | SAND MAY REPRESENT SEA CAVE<br>ASSUME CORE LOSS WAS IN SAND |

FR
SW
MW
HW
XW

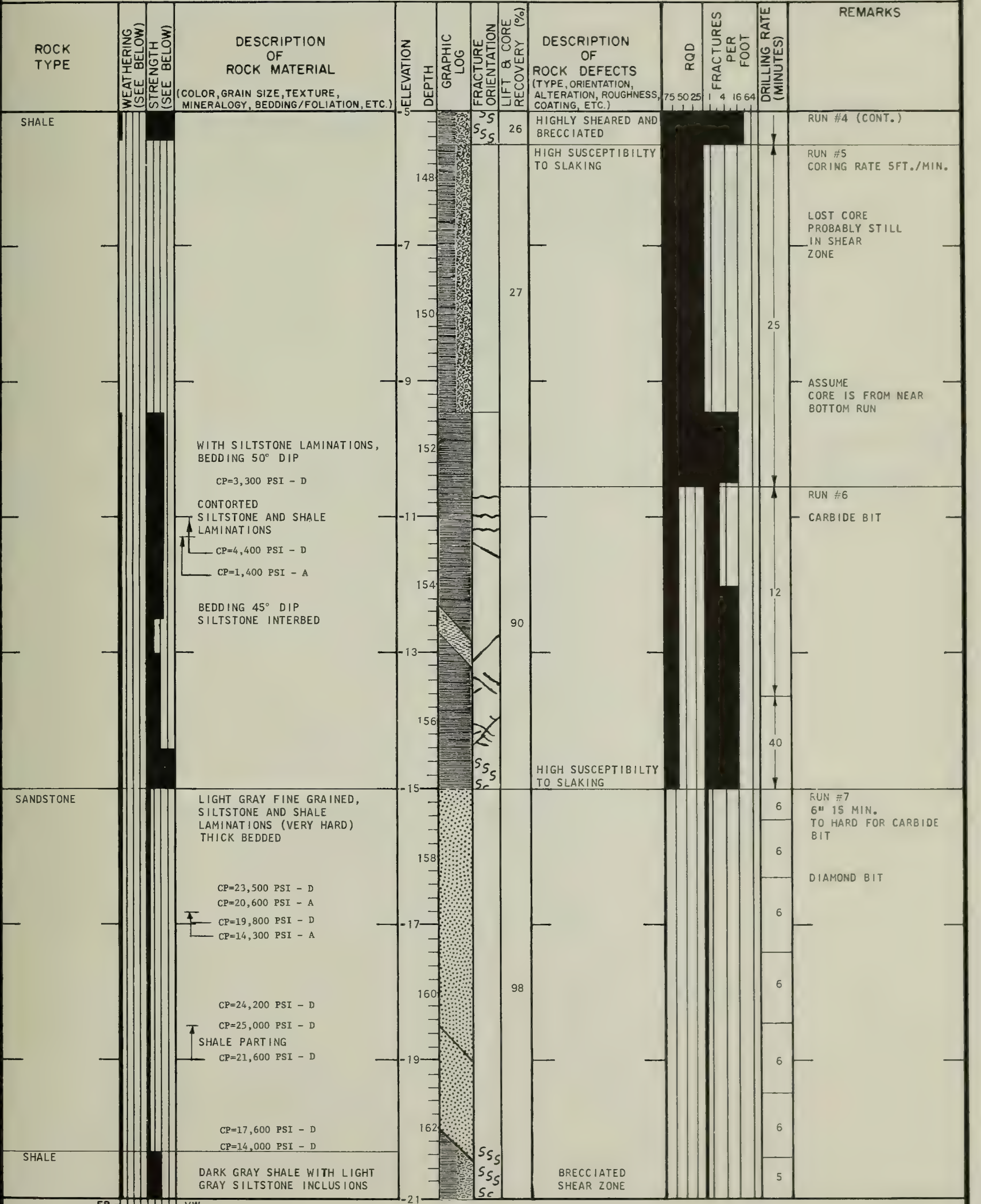
VW
W
MS
S
VS

## LOG OF BORING

**DAMES & MOORE**

PLATE A-10/2

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 15
PROJECT: RICHMOND TRANSPORT SEWER
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
ANGLE FROM HORIZONTAL 90°
LOCATION SUTRO HEIGHTS NEAR 48th. AVE.
ELEV. 142
PAGE 3 OF 4



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| SHALE | | -5 | | 26 | HIGHLY SHEARED AND BRECCIATED | | RUN #4 (CONT.) |
| | | -7<br>-9 | 148<br>150 | 27 | HIGH SUSCEPTIBILTY TO SLAKING | 25 | RUN #5<br>CORING RATE 5FT./MIN.<br>LOST CORE PROBABLY STILL IN SHEAR ZONE<br>ASSUME CORE IS FROM NEAR BOTTOM RUN |
| | WITH SILTSTONE LAMINATIONS, BEDDING 50° DIP<br>CP=3,300 PSI - D<br>CONTORTED SILTSTONE AND SHALE LAMINATIONS<br>CP=4,400 PSI - D<br>CP=1,400 PSI - A<br>BEDDING 45° DIP SILTSTONE INTERBED | -11<br>-13 | 152<br>154<br>156 | 90 | HIGH SUSCEPTIBILTY TO SLAKING | 12<br>40 | RUN #6<br>CARBIDE BIT |
| SANDSTONE | LIGHT GRAY FINE GRAINED, SILTSTONE AND SHALE LAMINATIONS (VERY HARD) THICK BEDDED<br>CP=23,500 PSI - D<br>CP=20,600 PSI - A<br>CP=19,800 PSI - D<br>CP=14,300 PSI - A<br>CP=24,200 PSI - D<br>CP=25,000 PSI - D<br>SHALE PARTING<br>CP=21,600 PSI - D<br>CP=17,600 PSI - D<br>CP=14,000 PSI - D | -15<br>-17<br>-19 | 158<br>160<br>162 | 98 | | 6<br>6<br>6<br>6<br>6<br>6 | RUN #7<br>6" 15 MIN.<br>TO HARD FOR CARBIDE BIT<br>DIAMOND BIT |
| SHALE | DARK GRAY SHALE WITH LIGHT GRAY SILTSTONE INCLUSIONS | -21 | | | BRECCIATED SHEAR ZONE | 5 | |

FR — VW
SW — W
MW — MS
HW — S
XW — VS

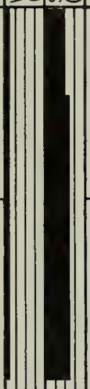
## LOG OF BORING

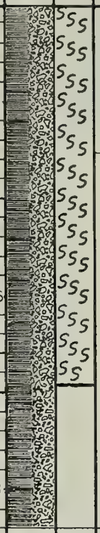
**DAMES & MOORE**

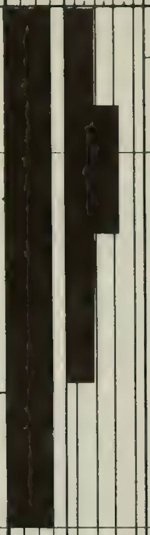
PLATE A-10/3

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 15
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION SUTRO HEIGHTS NEAR 48th. AVE.
ELEV. 142
PAGE 4 OF 4

| ROCK TYPE | WEATHERING (SEE BELOW) / STRENGTH (SEE BELOW) | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|---|
| SHALE | | DARK GRAY SHALE WITH LIGHT GRAY SILTSTONE INCLUSIONS | -21 | | 98 | BRECCIATED SHALE AND SILTSTONE<br>SHEAR ZONE<br>HIGH SUSCEPTIBILTY TO SLAKING | 5<br>5 | DIAMOND BIT |
| | | | -23 | 164 | 62 | HIGH SUSCEPTIBILTY TO SLAKING | | RUN #8 |
| | | | -25 | 166 | | | | ASSUME CORE LOSS WAS AT BOTTOM |
| | | | | 168 | | | | SHALE MAY BE WASHING OUT |
| | | | -27 | | | | | END OF BORING AT ELEV. -26.4' |







FR — SW — MW — HW — XW
VW — W — MS — S — VS

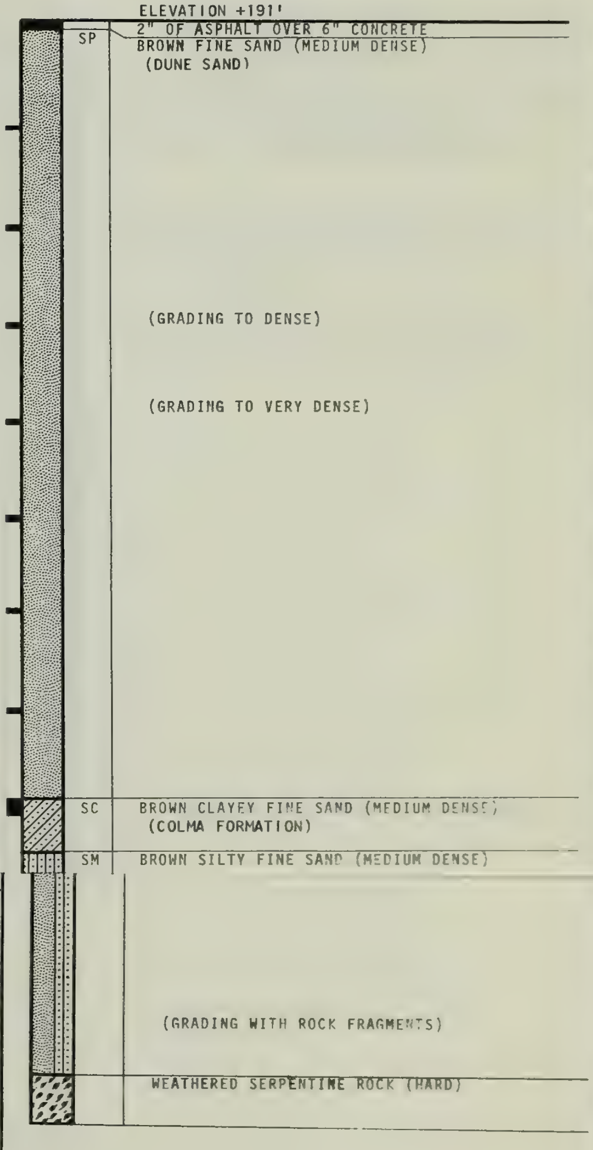
LOG OF BORING

DAMES & MOORE

PLATE A-10/4

## BORING 16
DRILLED 1/13-19/78

| Elevation | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS | | SHEAR STRENGTH TEST RESULTS | | | | | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT) or (HYD. PRESS., PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | LABORATORY | | | FIELD | | | | | |
| | | | | LIQUID LIMIT | PLASTIC LIMIT | TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | TORVANE (PSF) | PENETROMETER (PSF) | | | | |
| +200 | | | | | | | | | | | | | | |
| +190 | | | | | | | | | | | | | | |
| +180 | | 14 | 98 | | | | | | | | | U | 56 | 10 |
| +170 | | 9 | 101 | | | | | | | | | U | 75 | 16 |
| +160 | | 12 | 108 | | | | | | | | | U | 75 | 39 |
| +150 | | 23 | 100 | | | | | | | | | U | 75 | 55 |
| +140 | | 12 | 109 | | | | | | | | | U | 75 | 87 |
| +130 | | 13 | 110 | | | | | | | | | U | 82 | 50/5" |
| +120 | | 15 | 101 | | | | | | | | | U | 75 | 50/4" |
| +110 | | 14 | 120 | | | | | | | | | TW | 100 | 13 |
| -40 | | | | | | | | | | | | | | |
| -50 | | | | | | | | | | | | | | |
| -60 | | | | | | | | | | | | | | |
| -70 | | | | | | | | | | | | | | |



ELEVATION +191'

2" OF ASPHALT OVER 6" CONCRETE

SP BROWN FINE SAND (MEDIUM DENSE) (DUNE SAND)

(GRADING TO DENSE)

(GRADING TO VERY DENSE)

SC BROWN CLAYEY FINE SAND (MEDIUM DENSE) (COLMA FORMATION)

SM BROWN SILTY FINE SAND (MEDIUM DENSE)

(GRADING WITH ROCK FRAGMENTS)

WEATHERED SERPENTINE ROCK (HARD)

NOTES:

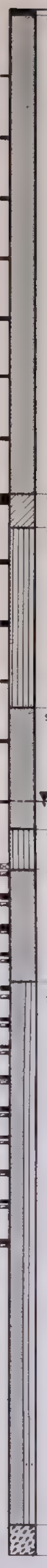
1. SAMPLING RESISTANCE:
   SPT DRIVEN BY 140# HAMMER FALLING 30"
   U AND TW DRIVEN BY 275# SLIPJARS FALLING 30"
2. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED ON OFFICIAL CITY GRADE.

# LOG OF BORING

**DAMES & MOORE**

## BORING 16
DRILLED 1/13-19/78

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | SHEAR STRENGTH TEST RESULTS, LABORATORY: TYPE OF TEST | SHEAR STRENGTH TEST RESULTS, LABORATORY: NORMAL OR CONFINING PRESSURE (PSF) | SHEAR STRENGTH TEST RESULTS, LABORATORY: PEAK SHEAR STRENGTH (PSF) | SHEAR STRENGTH TEST RESULTS, FIELD: TORVANE (PSF) | SHEAR STRENGTH TEST RESULTS, FIELD: PENETROMETER (PSF) | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT) or (HYD PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| +200 | | | | | | | | | | | | | | |
| +190 | | | | | | | | | | | | | | |
| +180 | | 14 | 98 | | | | | | | | | U | 56 | 10 |
| +170 | | 9 | 101 | | | | | | | | | U | 75 | 16 |
| +160 | | 12 | 108 | | | | | | | | | I | 75 | 39 |
| +150 | | 23 | 100 | | | | | | | | | U | 75 | 55 |
| +140 | | 12 | 109 | | | | | | | | | U | 75 | 87 |
| +130 | | 13 | 110 | | | | | | | | | U | 82 | 50/5" |
| +120 | | 15 | 101 | | | | | | | | | | 75 | 50/4" |
| +110 | | 14 | 120 | | | | | | | | | TW | 100 | 13 |
| +100 | SA (19%) | 1 | 113 | | | | | | | | | I | 75 | 23 |
| +90 | | 18 | 110 | | | | | | | | | U | 75 | 66 |
| 80 | | 14 | 110 | | | | | | | | | U | 75 | 70 |
| +70 | | 17 | 107 | | | DS/CD | 10300 | 6840 | | | | U | 83 | 50/6" |
| +60 | | 21 | 103 | | | | | | | | | U | 67 | 90/6" |
| +50 | | 17 | | | | | | | | | | U<br>SPT | 75<br>67 | 74<br>55/6" |
| | | 20 | 109 | | | | | | | | | U<br>SPT | 75<br>67 | 74<br>50/5" |
| +40 | | 21 | 108 | | | | | | | | | U<br>SPT | 75<br>67 | 89<br>50/6" |
| | | 24 | 103 | | | | | | | | | U<br>SPT | 67<br>67 | 52/6"<br>50/6" |
| +30 | SA (8 ) | 22 | 109 | | | | | | | | | U<br>SPT | 75<br>67 | 65<br>75/11" |
| | | 20 | 104 | | | DS/CD | 12000 | 7820 | | | | U<br>SPT | 75<br>83 | 78<br>50/5" |
| +20 | | 23 | 103 | | | | | | | | | U<br>SPT | 67<br>50 | 50/6"<br>50/6" |
| | PERM<br>SA<br>(37) | 26 | 101 | | | | | | | | | U<br>SPT | 67<br>82 | 50/6"<br>50/5" |
| +10 | | 25 | 102 | | | | | | | | | U<br>SPT | 79<br>89 | 85/11"<br>75/9" |
| | | 24 | 98 | | | DS/CD | 12000 | 7120 | | | | U<br>SPT | 67<br>67 | 58/6"<br>50/3" |
| 0 | | 20 | 111 | | | | | | | | | U<br>SPT | 67<br>67 | 50/3"<br>50/3" |
| | | 22 | 109 | | | | | | | | | U<br>SPT | 75<br>82 | 91<br>50/5" |
| 10 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | U<br>SPT | 75<br>67 | 99/11"<br>100/6" |
| 20 | | | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | | | |
| -40 | | | | | | | | | | | | | | |
| 50 | | | | | | | | | | | | | | |
| -60 | | | | | | | | | | | | | | |
| -70 | | | | | | | | | | | | | | |



ELEVATION +191'
2" OF ASPHALT OVER 6" CONCRETE
SP BROWN FINE SAND (MEDIUM DENSE)
(DUNE SAND)
(GRADING TO DENSE)
(GRADING TO VERY DENSE)
SC BROWN CLAYEY FINE SAND (MEDIUM DENSE)
(COLMA FORMATION)
SM BROWN SILTY FINE SAND (MEDIUM DENSE)
(GRADING LESS SILTY, VERY DENSE)
(GRADING LESS SILT )
SP REDDISH BROWN FINE SAND (VER DENSE)
(WATER LEVEL 2/15/78, 2/15/78)
SM DARK RED-BROWN SILTY FINE SAND (VERY DENSE
SP BROWN FINE SAND, SLIGHTLY SILTY (VERY DENSE)
GRADING TO BROWN
(GRADING LESS SILTY)
SP/SM BROWN SLIGHTLY SILTY FINE SAND (VERY DENSE)
(GRADING LESS SILTY)
(GRADING MORE SILTY)
(PARTIAL IRON OXIDE CEMENTATION)
(CLAYEY LENSES AT ELEVATION -35')
(GRADING WITH ROCK FRAGMENTS)
WEATHERED SERPENTINE ROCK (HARD)

NOTES:
1. SAMPLING RESISTANCE:
SPT DRIVEN BY 140# HAMMER FALLING 30"
U AND TW DRIVEN BY 275# SLIPJARS FALLING 30"
2. ELEVATIONS REFER TO SF DATUM AND ARE BASED ON OFFICIAL CITY GRADE.

# LOG OF BORING

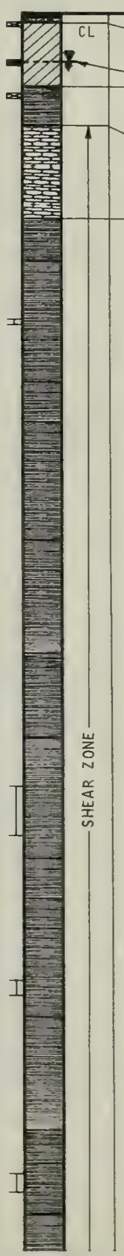
DAMES & MOORE

PLATE A-1P

# BORING 17

DRILLED 1/6-13/78

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS | | SHEAR STRENGTH TEST RESULTS | | | | | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT) or (HYD.PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | LABORATORY | | | FIELD | | | | | |
| | | | | LIQUID LIMIT | PLASTIC LIMIT | TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | TORVANE (PSF) | PENETROMETER (PSF) | | | | |
| +290 | | | | | | | | | | | | | | |
| +280 | | | | | | | | | | | | GRAB | N.A. | N.A. |
| | | | | | | | | | | | | U | 100 | 35 |
| | | | | | | | | | | | | TW | 100 | 42/6' |
| +270 | | | | | | | | | | | | | | |
| +260 | | | | | | | | | | | | | | |
| +250 | | | | | | | | | | | | PT | 80 | |
| +240 | | | | | | | | | | | | | | |
| +230 | | | | | | | | | | | | | | |
| +220 | | | | | | | | | | | | | | |
| +210 | | | | | | | | | | | | | | |
| +200 | | | | | | | | | | | 7<br>5<br>10<br>18<br>30 | NX | 42 | |
| +190 | | | | | | | | | | | | | | |
| | | | | | | | | | | | 23 | PT | 100 | |
| +180 | | | | | | | | | | | | | | |
| +170 | | | | | | | | | | | | | | |
| +160 | | | | | | | | | | | 22 | PT | 75 | |



ELEVATION +281.5'

3" AS ASPHALT ON TOP OF 5" CONCRETE

YELLOWISH BROWN SILTY CLAY WITH TRACE OF VERY FINE SAND AND ROCK FRAGMENTS (COLLUVIUM)

(ESTIMATED WATER LEVEL 2/15/78)

YELLOWISH BROWN SHALE, COMPLETELY WEATHERED TO A VERY SLIGHTLY SANDY SILTY CLAY (GRADING LESS WEATHERED, HARD)

CHERT, WITH CALCITE VEINS, FRACTURED

BLACK SHALE, HIGHLY SHEARED WITH HARD FRAGMENTS, HIGH SUSCEPTIBILITY TO SLAKING (SHALE MELANGE)

(GRAYWACKE INCLUSION, BRECCIATED)

(GRAYWACKE AND SERPENTINE INCLUSIONS, BRECCIATED)

(GRAYWACKE, SERPENTINE, AND SHALE INCLUSIONS, BRECCIATED)

(GRAYWACKE INCLUSION)

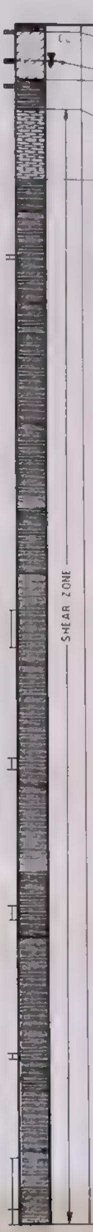
(GRAYWACKE AND SERPENTINE INCLUSIONS, HARD SHEARED SHALE MATRIX BECOMING MORE SANDY)

# LOG OF BORING

## BORING 17
DRILLED 1/6-13/78

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | SHEAR STRENGTH TEST RESULTS, LABORATORY: TYPE OF TEST | LABORATORY: NORMAL OR CONFINING PRESSURE (PSF) | LABORATORY: PEAK SHEAR STRENGTH (PSF) | FIELD: TORVANE (PSF) | FIELD: PENETROMETER (PSF) | CORING RATE (MIN/FT) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT) or (HYD. PRESS., PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| +280 | | | | | | | | | | | | GRAB | N.A. | N.A. |
| | | | | | | | | | | | | | 100 | 35 |
| | | | | | | | | | | | | TW | 100 | 42/6 |
| +250 | | | | | | | | | | | | PT | 80 | |
| +200 | | | | | | | | | | | 7<br>5<br>10<br>18<br>30 | NX | 42 | |
| +180 | | | | | | | | | | | 23 | PT | 100 | |
| +160 | | | | | | | | | | | 22 | PT | 75 | |
| +140 | | | | | | | | | | | 35 | PT | 100 | |
| | | | | | | | | | | | 25<br>30<br>15<br>35<br>30<br>25 | NX | 17 | |
| +120 | | | | | | | | | | | 10<br>20 | NX | 70 | |

Elevation scale: +290, +280, +270, +260, +250, +240, +230, +220, +210, +200, +190, +180, +170, +160, +150, +140, +130, +120, +110



ELEVATION +281.5

3" AS ASPHALT ON TOP OF 5" CONCRETE

YELLOWISH BROWN SILTY CLAY WITH TRACE OF VERY FINE SAND AND ROCK FRAGMENTS (COLLUVIUM)

(ESTIMATED WATER LEVEL 2/15/78)

YELLOWISH BROWN SHALE, COMPLETELY WEATHERED TO A VERY SLIGHTLY SANDY SILTY CLAY GRADING LESS WEATHERED, ARE)

CHERT, WITH CALCITE VEINS, FRACTURED

BLACK SHALE, HIGHLY SHEARED WITH HARD FRAGMENTS, HIGH SUSCEPTIBILITY TO SLAKING (SHALE MELANGE)

(GRAYWACKE INCLUSION, BRECCIATED)

(GRAYWACKE AND SERPENTINE INCLUSIONS, BRECCIATED)

(GRAYWACKE, SERPENTINE, AND SHALE INCLUSIONS, BRECCIATED)

(GRAYWACKE INCLUSION)

(GRAYWACKE AND SERPENTINE INCLUSIONS, HARD SHEARED SHALE MATRIX BECOMING MORE SANDY)

(SERPENTINE INCLUSION, GREEN, HARD)
(SHALE GRADING RED, SOFTER)

(SERPENTINE INCLUSION, GREEN, HARD)
(GRAYWACKE AND GREENSTONE INCLUSIONS, BRECCIATED)

(OCCASIONAL CHERT INCLUSIONS, RED, HARD, FRACTURED)

(GREENSTONE INCLUSION, GREEN, HARD, FRACTURED)

(SERPENTINE INCLUSION, GREEN, HARD, FRACTURED)

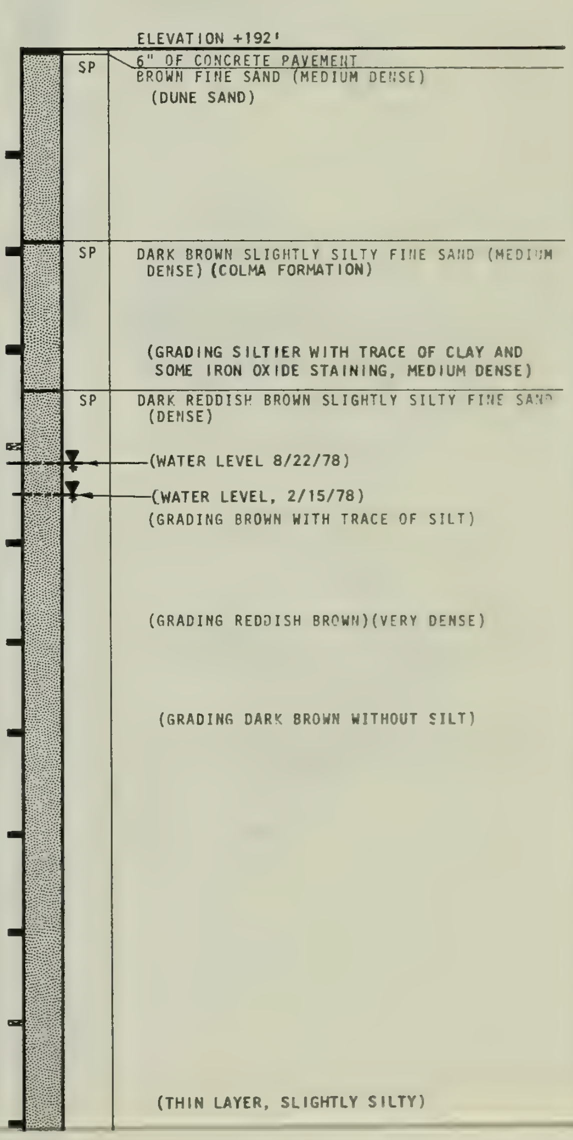
NOTES:
1. SAMPLING RESISTANCE:
U AND TW DRIVEN BY 340# SLIPJARS FALLING 18"
2. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED ON OFFICIAL CITY GRADE.

# LOG OF BORING

DAMES & MOORE

## BORING 18
DRILLED 1/20-24/78)

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS |  | SHEAR STRENGTH TEST RESULTS |  |  |  |  | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD.PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | LABORATORY |  |  | FIELD |  |  |  |  |  |
|  |  |  |  | LIQUID LIMIT | PLASTIC LIMIT | TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | TORVANE (PSF) | PENETROMETER (PSF) |  |  |  |  |
| +200 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| +190 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| +180 |  | 5 | 104 |  |  |  |  |  |  |  |  | U | 67 | 14 |
| +170 |  | 15 | 104 |  |  |  |  |  |  |  |  | U | 75 | 17 |
| +160 |  | 19 | 111 |  |  |  |  |  |  |  |  | U | 75 | 18 |
| +150 |  |  |  |  |  |  |  |  |  |  |  | U | 75 | 52 |
| +140 |  | 24 | 100 |  |  |  |  |  |  |  |  | U | 75 | 44 |
| +130 |  |  |  |  |  |  |  |  |  |  |  | U | 75 | 71 |
| +120 |  | 23 | 107 |  |  |  |  |  |  |  |  | U | 92 | 50/6" |
| +110 |  |  |  |  |  |  |  |  |  |  |  | U | 75 | 68 |
| +100 |  | 23 | 106 |  |  |  |  |  |  |  |  | U | 75 | 90 |
| +90 |  |  |  |  |  |  |  |  |  |  |  | U | 70 | 50/5" |
| +80 |  | 24 | 104 |  |  |  |  |  |  |  |  | U | 91 | 50 |



ELEVATION +192'

6" OF CONCRETE PAVEMENT

BROWN FINE SAND (MEDIUM DENSE)
(DUNE SAND)

DARK BROWN SLIGHTLY SILTY FINE SAND (MEDIUM DENSE) (COLMA FORMATION)

(GRADING SILTIER WITH TRACE OF CLAY AND SOME IRON OXIDE STAINING, MEDIUM DENSE)

DARK REDDISH BROWN SLIGHTLY SILTY FINE SAND (DENSE)

(WATER LEVEL 8/22/78)

(WATER LEVEL, 2/15/78)

(GRADING BROWN WITH TRACE OF SILT)

(GRADING REDDISH BROWN)(VERY DENSE)

(GRADING DARK BROWN WITHOUT SILT)

(THIN LAYER, SLIGHTLY SILTY)

[illegible]
U SAMPLER DRIVEN BY 275# SLIPJARS FALLING 30"
2. ELEVATIONS REFER TO SF DATUM AND ARE BASED ON OFFICIAL CITY GRADE.

# LOG OF BORING

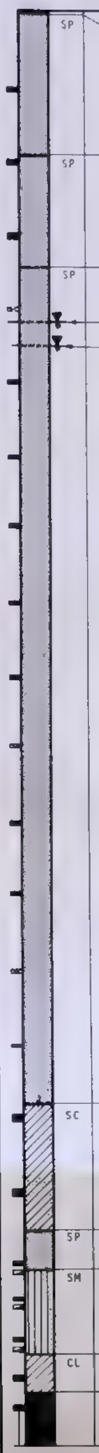
**DAMES & MOORE**

PLATE A-IR

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | SHEAR STRENGTH TEST RESULTS, LABORATORY: TYPE OF TEST | LABORATORY: NORMAL OR CONFINING PRESSURE (PSF) | LABORATORY: PEAK SHEAR STRENGTH (PSF) | FIELD: TORVANE (PSF) | FIELD: PENETROMETER (PSF) | CORING RATE (MIN/FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT.)or(HYD PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| +200 | | | | | | | | | | | | | | |
| +190 | | | | | | | | | | | | | | |
| +180 | | 5 | 104 | | | | | | | | | U | 67 | 14 |
| +170 | | 15 | 104 | | | | | | | | | U | 75 | 17 |
| +160 | | 19 | 111 | | | | | | | | | U | 75 | 18 |
| +150 | | | | | | | | | | | | U | 75 | 52 |
| +140 | | 24 | 100 | | | | | | | | | U | 75 | 44 |
| +130 | | | | | | | | | | | | U | 75 | 71 |
| +120 | | 23 | 107 | | | | | | | | | U | 92 | 50/6" |
| +110 | | | | | | | | | | | | U | 75 | 68 |
| +100 | | 23 | 106 | | | | | | | | | U | 75 | 90 |
| +90 | | | | | | | | | | | | U | 70 | 50/5" |
| +80 | | 24 | 104 | | | | | | | | | U | 91 | 50/5" |
| +70 | | 23 | 106 | | | DS/CD | 10400 | 7640 | | | | U | 73 | 50/5" |
| +60 | SA (3%) | 23 | | | | | | | | | | U | 79 | 50/5" |
| +50 | | 20 | 108 | | | | | | | | | U | 75 | 87 |
| +40 | | 16 | 117 | | | UC | | 3030 | | | | U | 92 | 42 |
| +30 | SA (32%) | 17 | 121 | | | | | | | | | U | 89 | 46 |
| | SA (7%) | 19 | 110 | | | DS/CD | 2000 | 9380 | | | | U | 82 | 50/5" |
| +20 | | | | | | | | | | | | SPT | 75 | 97/10" |
| | SA (41%) | 13 | 130 | | | | | | | | | U | 75 | 52/6" |
| | SA (17%) | | | | | | | | | | | SPT | 60 | 50/4" |
| | SA (39%) | 17 | 113 | | | DS/CD | 2000 | 9360 | | | | U | 78 | 90 |
| +10 | | | | | | | | | | | | SPT | 83 | 50/6" |
| | SA (51%) | 21 | 108 | | | | | | | | | U | 100 | 50/5" |
| | | | | | | | | | | | | U | 91 | 50/5" |
| 0 | | | | | | | | | | | 4<br>4<br>1½<br>1¼<br>4 | NX | 70 | |
| -10 | | | | | | | | | | | | | | |

# BORING 18

DRILLED 1/20-24/78)



ELEVATION +192'

SP — 6" OF CONCRETE PAVEMENT

BROWN FINE SAND (MEDIUM DENSE) (DUNE SAND)

SP — DARK BROWN SLIGHTLY SILTY FINE SAND (MEDIUM DENSE) (COLMA FORMATION)

(GRADING SILTIER WITH TRACE OF CLAY AND SOME IRON OXIDE STAINING, MEDIUM DENSE)

SP — DARK REDDISH BROWN SLIGHTLY SILTY FINE SAND (DENSE)

(WATER LEVEL 8/22/78)

(WATER LEVEL, 2/15/78)

(GRADING BROWN WITH TRACE OF SILT,

(GRADING REDDISH BROWN)(VERY DENSE)

(GRADING DARK BROWN WITHOUT SILT)

(THIN LAYER, SLIGHTLY SILTY)

SC — GRAYISH BROWN CLAYEY FINE SAND WITH YELLOW AND BLACK MOTTLING (DENSE TO VERY DENSE) (COLLUVIUM)

(GRADING WITH FRAGMENTS OF HIGHLY WEATHERED ROCK)

SP — BROWN SLIGHTLY CLAYEY FINE SAND WITH OCCASIONAL PIECES OF GRAVEL (VERY DENSE)

SM — BROWN SILTY FINE SAND WITH SOME ROCK FRAGMENTS (VERY DENSE)

CL — BROWN GRAVELLY FINE SANDY SILTY CLAY WITH YELLOW AND BLACK MOTTLING (HARD)

BLACK SHALE MODERATELY WEATHERED HIGHLY FRACTURED WITH IRON OXIDE STAINING, RQD=0

NOTES:

1. SAMPLING RESISTANCE:
   SPT DRIVEN BY 140# HAMMER FALLING 30"
   U SAMPLER DRIVEN BY 275# SLIPJARS FALLING 30"
2. ELEVATIONS REFER TO SF DATUM AND ARE BASED ON OFFICIAL CITY GRADE.

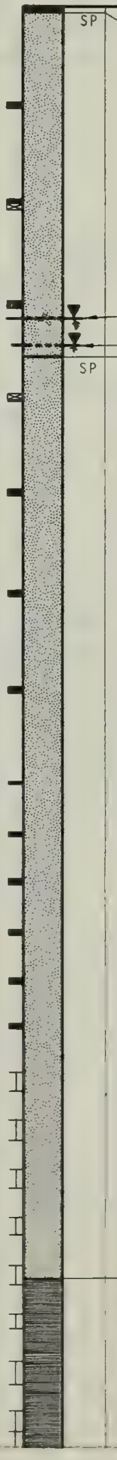
# LOG OF BORING

DAMES & MOORE

# BORING 19

DRILLED 1/18-24/78

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS |  | SHEAR STRENGTH TEST RESULTS |  |  |  |  | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT) or (HYD. PRESS., PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | LABORATORY |  |  | FIELD |  |  |  |  |  |
|  |  |  |  | LIQUID LIMIT | PLASTIC LIMIT | TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | TORVANE (PSF) | PENETROMETER (PSF) |  |  |  |  |
| +150 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| +140 |  | 17 | 112 |  |  |  |  |  |  |  |  | TW | 67 | 54 |
| +130 |  | 17 | 110 |  |  |  |  |  |  |  |  | TW | 67 | 69 |
| +120 |  | 18 | 106 |  |  |  |  |  |  |  |  | TW | 100 | 34 |
| +110 |  | 18 | 105 |  |  |  |  |  |  |  |  | TW | 67 | 77 |
| +100 |  | 20<br>21 | 106<br>109 |  |  |  |  |  |  |  |  | TW | 100 | 50/2" |
| +90 |  | 20 | 109 |  |  |  |  |  |  |  |  | U | 100 | 80/11" |
| +80 |  | 20 | 108 |  |  | DS/CD | 6400 | 5100 |  |  |  | U | 100 | 81/11" |
| +70 |  | 23 | 108 |  |  |  |  |  |  |  |  | U | 100 | 100/5 1/2" |
|  |  | 24 | 104 |  |  |  |  |  |  |  |  | U | 100 | 51/5" |
| +60 |  | 23 | 103 |  |  | DS/CD | 7800 | 5640 |  |  |  | U | 100 | 100/5" |
|  |  | 23 | 103 |  |  |  |  |  |  |  |  | U | 100 | 60/3" |
| +50 |  | 24 |  |  |  |  |  |  |  |  |  | U | 100 | 90/6" |
|  |  | 21 | 107 |  |  | DS/CD | 8800 | 6060 |  |  |  | U | 100 | 70/3" |
| +40 |  |  |  |  |  |  |  |  |  |  |  | PT | 80 |  |
|  |  |  |  |  |  |  |  |  |  |  |  | PT | 100 |  |
| +30 |  |  |  |  |  |  |  |  |  |  |  | PT | 80 |  |
|  |  |  |  |  |  |  |  |  |  |  |  | PT | 95 |  |
| +20 |  |  |  |  |  |  |  |  |  |  |  | PT | NR |  |
|  |  |  |  |  |  |  |  |  |  |  |  | PT |  |  |
| +10 |  |  |  |  |  |  |  |  |  |  |  | PT | 100 |  |
|  |  |  |  |  |  |  |  |  |  |  |  | PT | 95 |  |
|  |  |  |  |  |  |  |  |  |  |  | 25 | NX | 78 |  |



ELEVATION +150.5'

7" THICK ASPHALT PAVEMENT

BROWN FINE SAND (DENSE)
(DUNE SAND)

(GRADING VERY DENSE)

(GRADING DENSE)

(WATER LEVEL 8/22/78)

(WATER LEVEL, 2/15/78)

REDDISH BROWN FINE SAND WITH TRACE OF SILT
(VERY DENSE)
(COLMA FORMATION)

(GRADING SLIGHTLY MORE SILTY)

(LENS OF CLAY)

(GRADING LESS SILTY AND WITH INTERMITTANT IRON OXIDE CEMENTATION)

(GRADING BROWN)

DARK BROWN SHALE WITH LAMINATIONS OF SILTSTONE, HIGHLY WEATHERED TO A SILTY CLAY WITH ROCK FRAGMENTS (VERY STIFF)

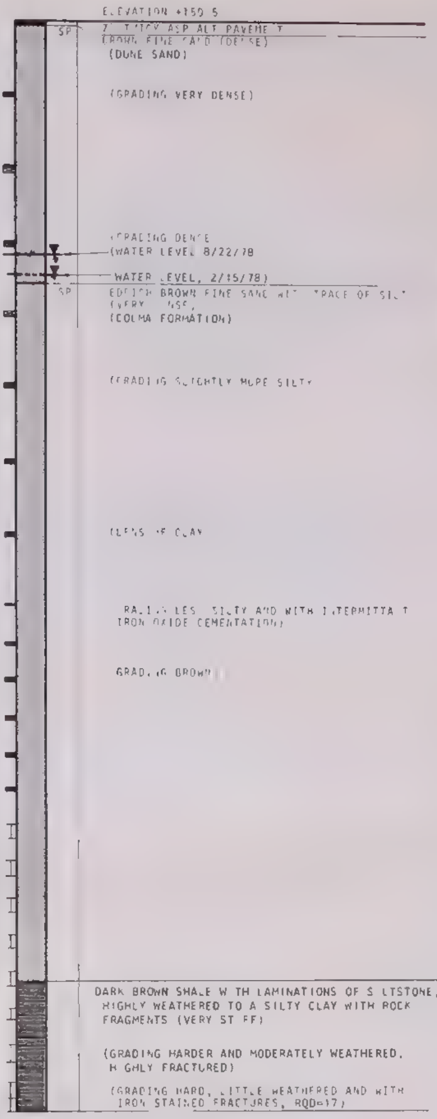
(GRADING HARDER AND MODERATELY WEATHERED, HIGHLY FRACTURED)

(GRADING HARD, LITTLE WEATHERED AND WITH IRON-STAINED FRACTURES, RQD=17)

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | SHEAR STRENGTH TEST RESULTS, LABORATORY: TYPE OF TEST | LABORATORY: NORMAL OR CONFINING PRESSURE (PSF) | LABORATORY: PEAK SHEAR STRENGTH (PSF) | FIELD: TORVANE (PSF) | FIELD: PENETROMETER (PSF) | CORING RATE (MIN/FT) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT) or (HYD PRESS, PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| +150 | | | | | | | | | | | | | | |
| +140 | | 17 | 112 | | | | | | | | | TW | 67 | 54 |
| +130 | | 17 | 110 | | | | | | | | | TW | 67 | 69 |
| +120 | | 18 | 106 | | | | | | | | | TW | 100 | 34 |
| +110 | | 18 | 105 | | | | | | | | | TW | 67 | 77 |
| +100 | | 20<br>21 | 106<br>109 | | | | | | | | | TW | 100 | 50/3" |
| +90 | | 20 | 109 | | | | | | | | | U | 100 | 80/11" |
| +80 | | 20 | 108 | | | DS/CD | 6400 | 5100 | | | | U | 100 | 81/11" |
| +70 | | 23 | 108 | | | | | | | | | U | 100 | 100/5 1/2" |
| | | 24 | 104 | | | | | | | | | U | 100 | 51/5" |
| +60 | | 23 | 103 | | | DS/CD | 7800 | 5640 | | | | U | 100 | 100/5" |
| | | 23 | 103 | | | | | | | | | U | 100 | 60/3" |
| +50 | | 24 | | | | | | | | | | U | 100 | 90/6" |
| | | 21 | 107 | | | DS/CD | 8800 | 6060 | | | | U | 100 | 70/3" |
| +40 | | | | | | | | | | | | PT | 80 | |
| | | | | | | | | | | | | PT | 100 | |
| +30 | | | | | | | | | | | | PT | 80 | |
| | | | | | | | | | | | | PT | 95 | |
| +20 | | | | | | | | | | | | PT | NR | |
| | | | | | | | | | | | | PT | | |
| +10 | | | | | | | | | | | | PT | 100 | |
| | | | | | | | | | | | | PT | 95 | |
| | | | | | | | | | | | 25<br>24 | NX | 78 | |
| 0 | | | | | | | | | | | | | | |

# BORING 19

DRILLED 1/18-24/78



ELEVATION +150.5

7" THICK ASPHALT PAVEMENT

SP BROWN FINE SAND (DENSE)
(DUNE SAND)

(GRADING VERY DENSE)

(GRADING DENSE)
(WATER LEVEL 8/22/78)
(WATER LEVEL, 2/15/78)

SP REDDISH BROWN FINE SAND WITH TRACE OF SILT
(VERY DENSE)
(COLMA FORMATION)

(GRADING SLIGHTLY MORE SILTY)

(LENS OF CLAY)

(GRADING LESS SILTY AND WITH INTERMITTANT
IRON OXIDE CEMENTATION)

(GRADING BROWN)

DARK BROWN SHALE WITH LAMINATIONS OF SILTSTONE,
HIGHLY WEATHERED TO A SILTY CLAY WITH ROCK
FRAGMENTS (VERY STIFF)

(GRADING HARDER AND MODERATELY WEATHERED,
HIGHLY FRACTURED)

(GRADING HARD, LITTLE WEATHERED AND WITH
IRON STAINED FRACTURES, RQD=17)

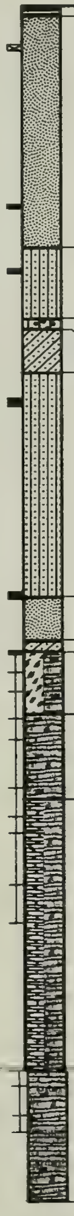
NOTES

1. SAMPLING RESISTANCE
U AND TW DRIVEN BY 320# SLIP JARS FALLING 14"
2. ELEVATIONS REFER TO SF DATUM AND ARE BASED ON OFFICIAL CITY GRADE.

# LOG OF BORING

## BORING 20
DRILLED 3/14-23/78

| ELEVATION | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS |  | SHEAR STRENGTH TEST RESULTS |  |  |  |  | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD.PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | LABORATORY |  |  | FIELD |  |  |  |  |  |
|  |  |  |  | LIQUID LIMIT | PLASTIC LIMIT | TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | TORVANE (PSF) | PENETROMETER (PSF) |  |  |  |  |
| +240 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  | GRAB | N.A. | N.A. |
| +230 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| +220 |  |  |  |  |  |  |  |  |  |  |  | TW | 67 | 95 |
|  | PERM<br>SA<br>(35%) | 15 | 118 |  |  |  |  |  |  |  |  | U | 100 | 26 |
| +210 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| +200 | PERM<br>SA<br>(22%) | 18 | 115 |  |  |  |  |  |  |  |  | U | 100 | 73 |
| +190 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| +180 | SA<br>(10%) | 28 | 97 |  |  |  |  |  |  |  |  | U | 100 | 105 |
|  |  |  |  |  |  |  |  |  |  |  | 4<br>9<br>14<br>9 | U | 100 | 100/5.5 |
|  |  |  |  |  |  |  |  |  |  |  |  | NX | 25 |  |
| +170 |  |  |  |  |  |  |  |  |  |  | 10<br>15<br>9<br>6 | NX | 100 |  |
|  |  |  |  |  |  |  |  |  |  |  |  | NX | 100 |  |
|  |  |  |  |  |  |  |  |  |  |  | 14<br>17<br>20<br>13 | NX | 50 |  |
|  |  |  |  |  |  |  |  |  |  |  | 5<br>3 | NX | 0 |  |
| +160 |  |  |  |  |  |  |  |  |  |  | 11<br>9<br>13 | NX | 30 |  |
|  |  |  |  |  |  |  |  |  |  |  | 14<br>9<br>7<br>7 | NX | 0 |  |
|  |  |  |  |  |  |  |  |  |  |  | 5 | NX | 5 |  |
| +150 |  |  |  |  |  |  |  |  |  |  | 6<br>9<br>4<br>4<br>4 | NX | 0 |  |
| +140 |  |  |  |  |  |  |  |  |  |  | 4 MIN/FT AVG. |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  | 23<br>25 | NX | 0 |  |
| +10 |  |  |  |  |  |  |  |  |  |  | 22<br>13 | NX | 0 |  |
|  |  |  |  |  |  |  |  |  |  |  | 17<br>11<br>6<br>6<br>6<br>10<br>13<br>10 | NX | 30 |  |
| 0 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |



ELEVATION +240'

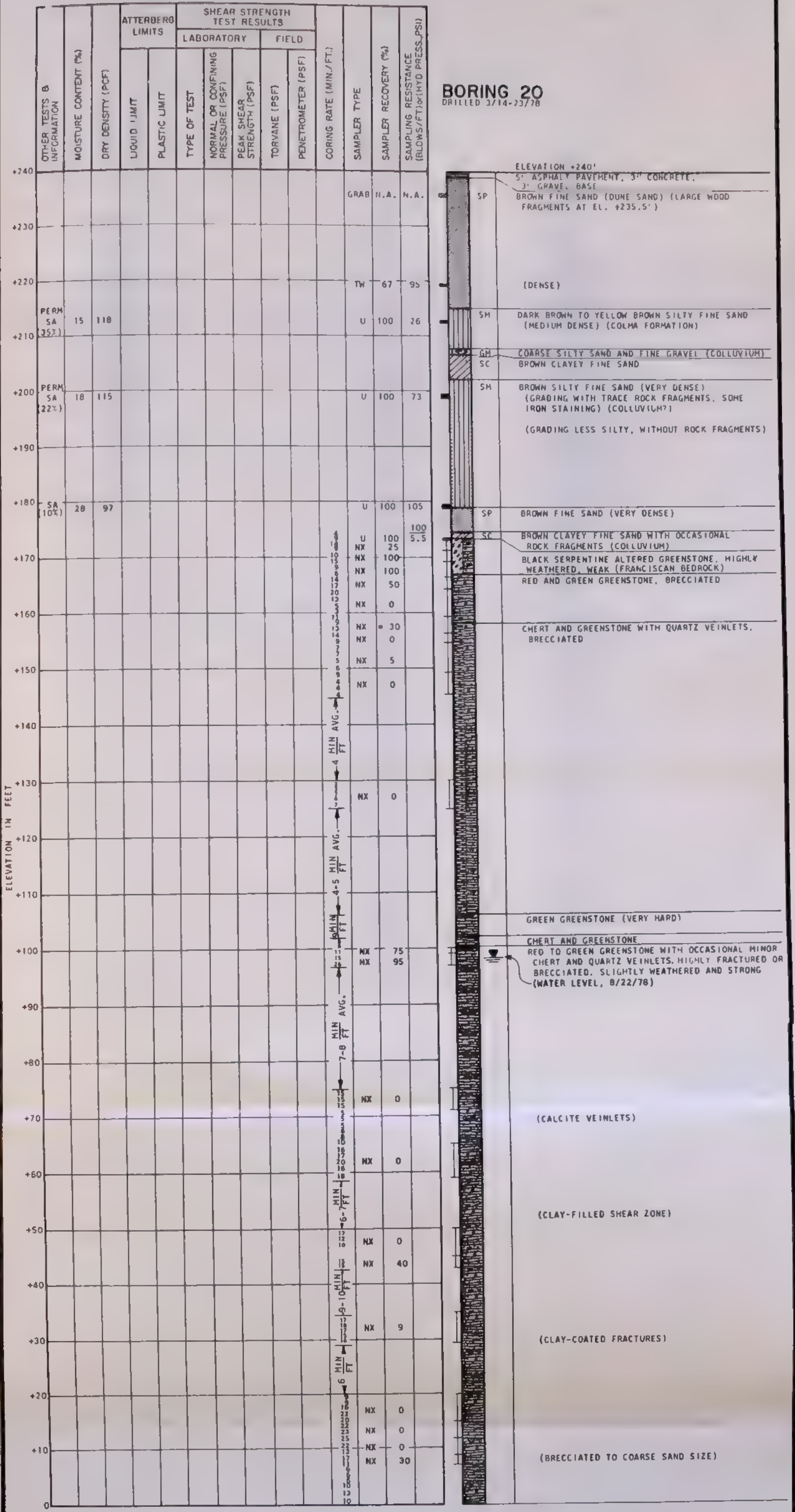
|  |  |
|---|---|
|  | 5" ASPHALT PAVEMENT, 3" CONCRETE, 3" GRAVEL BASE |
| SP | BROWN FINE SAND (DUNE SAND) (LARGE WOOD FRAGMENTS AT EL. +235.5')<br>(DENSE) |
| SM | DARK BROWN TO YELLOW BROWN SILTY FINE SAND (MEDIUM DENSE) (COLMA FORMATION) |
| GM | COARSE SILTY SAND AND FINE GRAVEL (COLLUVIUM) |
| SC | BROWN CLAYEY FINE SAND |
| SM | BROWN SILTY FINE SAND (VERY DENSE) (GRADING WITH TRACE ROCK FRAGMENTS, SOME IRON STAINING) (COLLUVIUM?)<br>(GRADING LESS SILTY, WITHOUT ROCK FRAGMENTS) |
| SP | BROWN FINE SAND (VERY DENSE) |
| SC | BROWN CLAYEY FINE SAND WITH OCCASIONAL ROCK FRAGMENTS (COLLUVIUM) |
|  | BLACK SERPENTINE ALTERED GREENSTONE, HIGHLY WEATHERED, WEAK (FRANCISCAN BEDROCK) |
|  | RED AND GREEN GREENSTONE, BRECCIATED |
|  | CHERT AND GREENSTONE WITH QUARTZ VEINLETS, BRECCIATED<br>(BRECCIATED TO COARSE SAND SIZE) |

NOTE:
1. SAMPLING RESISTANCE:
   U AND TW DRIVEN WITH A 300 POUND SLIPJARS FALLING 18"
2. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED ON OFFICIAL CITY GRADE
3. REFER TO FOLLOWING GEOLOGIC LOGS FOR MORE DETAILED DESCRIPTION OF THE BEDROCK

# LOG OF BORING

**DAMES & MOORE**

# BORING 20
DRILLED 3/14-23/78



| OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | SHEAR STRENGTH TEST RESULTS, LABORATORY: TYPE OF TEST | LABORATORY: NORMAL OR CONFINING PRESSURE (PSF) | LABORATORY: PEAK SHEAR STRENGTH (PSF) | FIELD: TORVANE (PSF) | FIELD: PENETROMETER (PSF) | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)&(HYD PRESS,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | GRAB | N.A. | N.A. |
| | | | | | | | | | | | TW | 67 | 95 |
| PERM SA (35%) | 15 | 118 | | | | | | | | | U | 100 | 26 |
| PERM SA (22%) | 18 | 115 | | | | | | | | | U | 100 | 73 |
| SA (10%) | 28 | 97 | | | | | | | | | U | 100 | 105 |
| | | | | | | | | | | | U | 100 | 100/5.5 |
| | | | | | | | | | | | NX | 25 | |
| | | | | | | | | | | | NX | 100 | |
| | | | | | | | | | | | NX | 100 | |
| | | | | | | | | | | | NX | 50 | |
| | | | | | | | | | | | NX | 0 | |
| | | | | | | | | | | | NX | 30 | |
| | | | | | | | | | | | NX | 0 | |
| | | | | | | | | | | | NX | 5 | |
| | | | | | | | | | | | NX | 0 | |
| | | | | | | | | | | | NX | 0 | |
| | | | | | | | | | | | NX | 75 | |
| | | | | | | | | | | | NX | 95 | |
| | | | | | | | | | | | NX | 0 | |
| | | | | | | | | | | | NX | 0 | |
| | | | | | | | | | | | NX | 0 | |
| | | | | | | | | | | | NX | 40 | |
| | | | | | | | | | | | NX | 9 | |
| | | | | | | | | | | | NX | 0 | |
| | | | | | | | | | | | NX | 0 | |
| | | | | | | | | | | | NX | 0 | |
| | | | | | | | | | | | NX | 30 | |

ELEVATION +240'

5' ASPHALT PAVEMENT, 3" CONCRETE, 3' GRAVEL BASE

SP BROWN FINE SAND (DUNE SAND) (LARGE WOOD FRAGMENTS AT EL. +235.5')

(DENSE)

SM DARK BROWN TO YELLOW BROWN SILTY FINE SAND (MEDIUM DENSE) (COLMA FORMATION)

GM COARSE SILTY SAND AND FINE GRAVEL (COLLUVIUM)

SC BROWN CLAYEY FINE SAND

SM BROWN SILTY FINE SAND (VERY DENSE) (GRADING WITH TRACE ROCK FRAGMENTS, SOME IRON STAINING) (COLLUVIUM?)

(GRADING LESS SILTY, WITHOUT ROCK FRAGMENTS)

SP BROWN FINE SAND (VERY DENSE)

SC BROWN CLAYEY FINE SAND WITH OCCASIONAL ROCK FRAGMENTS (COLLUVIUM)

BLACK SERPENTINE ALTERED GREENSTONE, HIGHLY WEATHERED, WEAK (FRANCISCAN BEDROCK)

RED AND GREEN GREENSTONE, BRECCIATED

CHERT AND GREENSTONE WITH QUARTZ VEINLETS, BRECCIATED

GREEN GREENSTONE (VERY HARD)

CHERT AND GREENSTONE

RED TO GREEN GREENSTONE WITH OCCASIONAL MINOR CHERT AND QUARTZ VEINLETS. HIGHLY FRACTURED OR BRECCIATED. SLIGHTLY WEATHERED AND STRONG

(WATER LEVEL, 8/22/78)

(CALCITE VEINLETS)

(CLAY-FILLED SHEAR ZONE)

(CLAY-COATED FRACTURES)

(BRECCIATED TO COARSE SAND SIZE)

NOTE:

1. SAMPLING RESISTANCE: U AND TW DRIVEN WITH A 300 POUND SLIPJARS FALLING 18"
2. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED ON OFFICIAL CITY GRADE
3. REFER TO FOLLOWING GEOLOGIC LOGS FOR MORE DETAILED DESCRIPTION OF THE BEDROCK

## LOG OF BORING

DAMES & MOORE

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)

BORING NO. 20

PROJECT: RICHMOND TRANSPORT SEWER

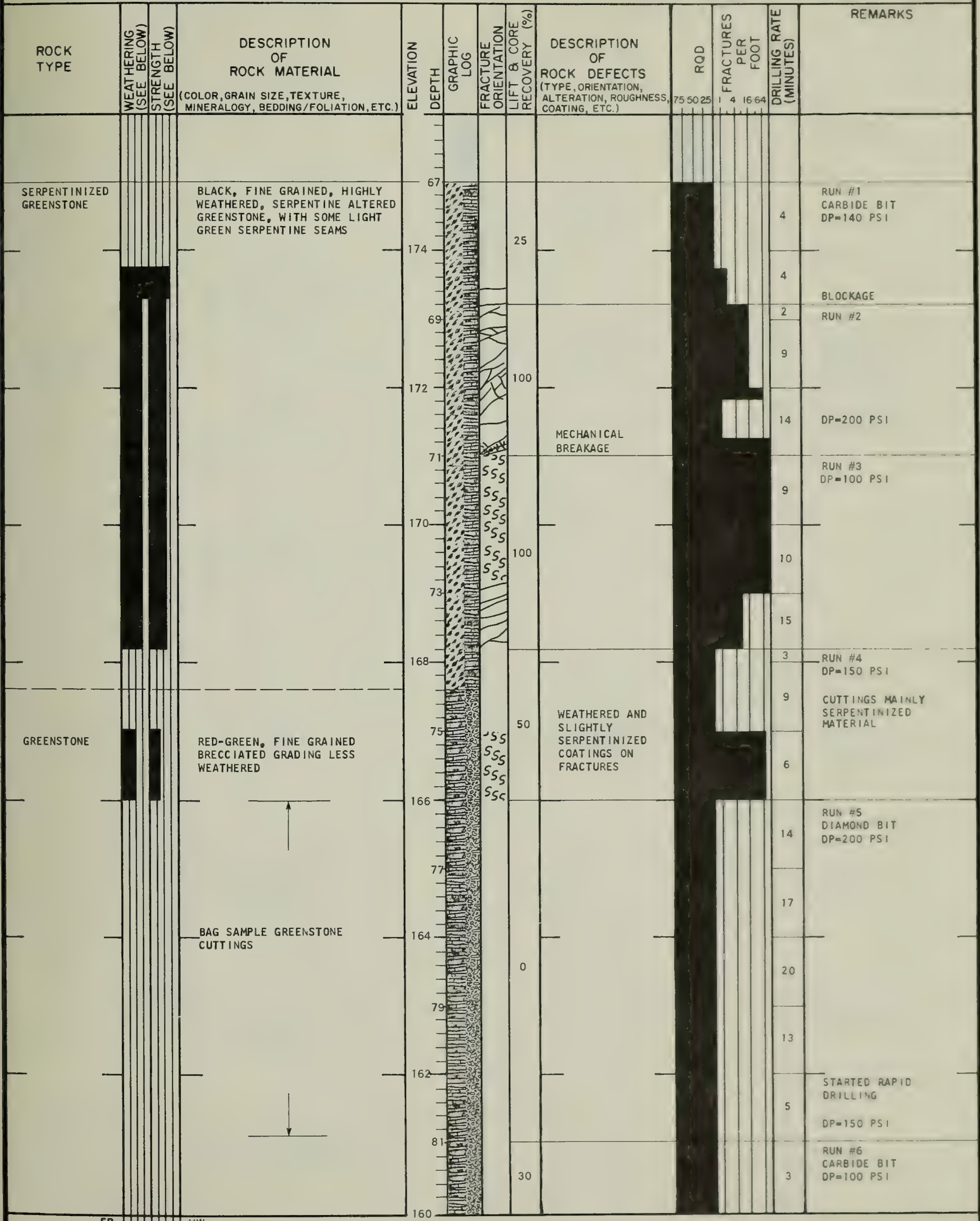
ANGLE FROM HORIZONTAL 90°

DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY

LOCATION 34th. AVE. NEAR GEARY

ELEV. 240

PAGE 1 OF 7



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| SERPENTINIZED GREENSTONE | BLACK, FINE GRAINED, HIGHLY WEATHERED, SERPENTINE ALTERED GREENSTONE, WITH SOME LIGHT GREEN SERPENTINE SEAMS | | 67 | | | 4 | RUN #1<br>CARBIDE BIT<br>DP=140 PSI |
| | | 174 | | 25 | | 4 | BLOCKAGE |
| | | | 69 | | | 2 | RUN #2 |
| | | 172 | | 100 | | 9 | |
| | | | | | MECHANICAL BREAKAGE | 14 | DP=200 PSI |
| | | | 71 | | | 9 | RUN #3<br>DP=100 PSI |
| | | 170 | | 100 | | 10 | |
| | | | 73 | | | 15 | |
| | | 168 | | | | 3 | RUN #4<br>DP=150 PSI |
| | | | | 50 | WEATHERED AND SLIGHTLY SERPENTINIZED COATINGS ON FRACTURES | 9 | CUTTINGS MAINLY SERPENTINIZED MATERIAL |
| GREENSTONE | RED-GREEN, FINE GRAINED BRECCIATED GRADING LESS WEATHERED | | 75 | | | 6 | |
| | | 166 | | | | 14 | RUN #5<br>DIAMOND BIT<br>DP=200 PSI |
| | BAG SAMPLE GREENSTONE CUTTINGS | | 77 | | | 17 | |
| | | 164 | | 0 | | 20 | |
| | | | 79 | | | 13 | |
| | | 162 | | | | 5 | STARTED RAPID DRILLING<br>DP=150 PSI |
| | | | 81 | 30 | | 3 | RUN #6<br>CARBIDE BIT<br>DP=100 PSI |
| | | 160 | | | | | |

FR — SW — MW — HW — XW

VW — W — MS — S — VS

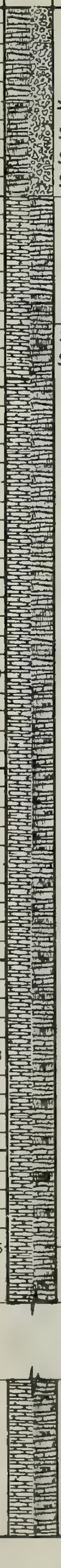
## LOG OF BORING

**DAMES & MOORE**

PLATE A-IT/1

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 20
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION 34th. AVE. NEAR GEARY
ELEV. 240
PAGE 2 OF 7

| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| GREENSTONE | BRECCIATED WITH SERPENTINE VEINLETS | 160 | 83 | 30 | SLIGHTLY WEATHERED FRACTURES | 11<br>9 | RUN #6 (CONT.)<br>DP = 175PSI |
| CHERT AND GREENSTONE | BAG SAMPLE GREENSTONE AND CHERT CUTTINGS | 158 | 85 | 0 | | 13<br>11 | RUN #7<br>VERY HARD CHERT ? |
| | BAG SAMPLE GREENSTONE AND CHERT CUTTINGS | 156<br>154<br>152 | 87<br>89 | 5 | QUARTZ VEINLETS | 14<br>9<br>7<br>7<br>5<br>6 | RUN #8<br>DP = 250PSI<br>DIAMOND BIT<br>DP = 200 PSI<br>CHERT AND GREENSTONE PEBBLES IN BIT |
| | BAG SAMPLE GREENSTONE AND CHERT CUTTINGS | 150<br>148 | 91<br>93<br>95 | 0 | | 9<br>4<br>4<br>4 | RUN #9<br>DP = 200 PSI<br>CARBIDE BIT |
| | 15 FEET TRICONE DRILLING | | | | | AVERAGE RATE 4 MIN/FT | TRICONE BIT<br>DP = 200 PSI<br>1 FOOT CAVE IN OVER-NIGHT |
| | BAG SAMPLE GREENSTONE, CHERT AND QUARTZ CUTTINGS | 130 | | | | | |



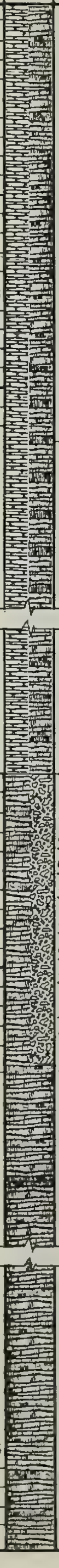
WEATHERING (SEE BELOW): FR, SW, MW, HW, XW
STRENGTH (SEE BELOW): VW, W, MS, S, VS

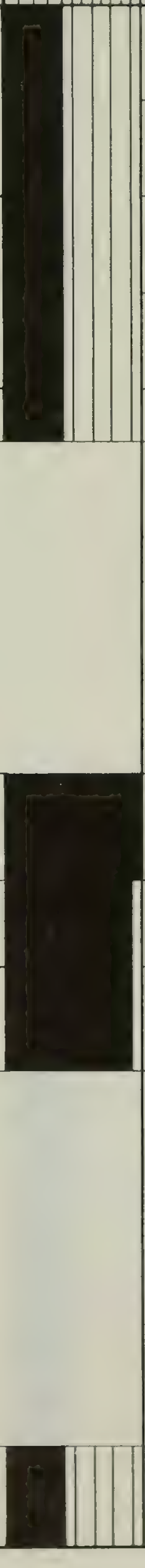
RQD 75 50 25
FRACTURES PER FOOT 1 4 16 64
FRACTURE ORIENTATION

# LOG OF BORING

DAMES & MOORE

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03) BORING NO. 20
PROJECT: RICHMOND TRANSPORT SEWER
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY ANGLE FROM HORIZONTAL 90°
LOCATION 34th. AVE. NEAR GEARY ELEV. 240 PAGE 3 OF 7





| ROCK TYPE | WEATHERING (SEE BELOW) | STRENGTH (SEE BELOW) | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | FRACTURE ORIENTATION | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | RQD 75 50 25 | FRACTURES PER FOOT 1 4 16 64 | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GREENSTONE AND CHERT | | | | 130 | | | | | | | 2 | RUN #10<br>DP=200 PSI |
| | | | | | 111 | | | | | | 3 | |
| | | | BAG SAMPLE GREENSTONE, CHERT AND QUARTZ VEINLET CUTTINGS | 128 | | | 0 | | | | 7 | DP=140-160 PSI |
| | | | | | 113 | | | | | | 6 | DP=140 PSI |
| | | | | 126 | | | | | | | 7 | |
| | | | 25.5' OF TRICONE DRILLING | | | | | | | | AVG. 4-5 MIN/FT | TRICONE BIT<br>DP=180-200 PSI |
| | | | GREEN GREENSTONE<br>VERY HARD DRILLING 134-138' | | | | | | | | AVG. 9 MIN/FT | COLOR CHANGE AT 134' |
| | | | | | | | | | | | AVG. 6 MIN/FT | |
| GREENSTONE | | | RED TO GREEN, FINE GRAINED, CALCITE AND QUARTZ VEINLETS, BRECCIATED | 100 | | SSS | 75 | SOME SLICKENSIDED FRACTURES QUARTZ AND CALCITE VEINLETS | | | 11 | RUN #11<br>DP=200 PSI |
| | | | | | 141 | SSS | | | | | 15 | RUN #12<br>DP=240 PSI |
| | | | | 98 | | SSS | 95 | | | | 26 | CORE BARREL PLUGGED |
| | | | | | 143 | | | | | | | |
| | | | 21.9' TRICONE DRILLING<br>GREENSTONE AND QUARTZ CUTTING | | | | | WEATHERED HALOS ALONG FRACTURES | | | AVG. 7-8 MIN/FT | TRICONE BIT<br>DP=160-220 PSI |
| | | | GREENSTONE CUTTINGS | | 165 | | 0 | | | | 15 | RUN #13<br>DP=240 PSI |
| | | | | 74 | | | | | | | | |

FR — SW — MW — HW — XW
VW — W — MS — S — VS

## LOG OF BORING

DAMES & MOORE

PLATE A-17/3

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 20
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION 34th. AVE. NEAR GEARY
ELEV. 240
PAGE 4 OF 7

| DEPTH | ELEVATION | ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | LIFT & CORE RECOVERY (%) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|
| 166–167 | 74 | GREENSTONE AND MINOR CHERT | BAG SAMPLE OF GREENSTONE CUTTINGS | 0 | 15 | RUN #13 (CONT)<br>DP = 22 PSI |
| 167–168 | | | | | 15 | |
| 168–169 | 72 | | | | 15 | |
| 169–170 | | | 6 FEET TRICONE DRILLING<br>BAG SAMPLE OF GREENSTONE CUTTINGS WITH SOME CHERT AND CALCITE VEINLETS | | ? | TRICONE DRILLING |
| 170–171 | 70 | | | | 5 | |
| 171–172 | | | | | 5 | |
| 172–173 | 68 | | | | 5 | |
| 173–174 | | | | | 6 | |
| 174–175 | 66 | | | | 8 | |
| 175–176 | | | BAG SAMPLE OF GREENSTONE CUTTINGS WITH SOME CHERT AND CALCITE VEINLETS | 0 | 10 | RUN #14<br>DP = 180 PSI |
| 176–177 | 64 | | | | 16 | |
| 177–178 | | | | | 17 | DP = 200 PSI |
| 178–179 | 62 | | | | 20 | |
| 179–180 | | | | | 16 | |
| 180–181 | 60 | | | | 18 | |
| 181– | | | 9 FEET TRICONE DRILLING | | | TRICONE DRILLING<br>APPROX. 1 FOOT OF SLOUGH IN HOLE 181-190 |

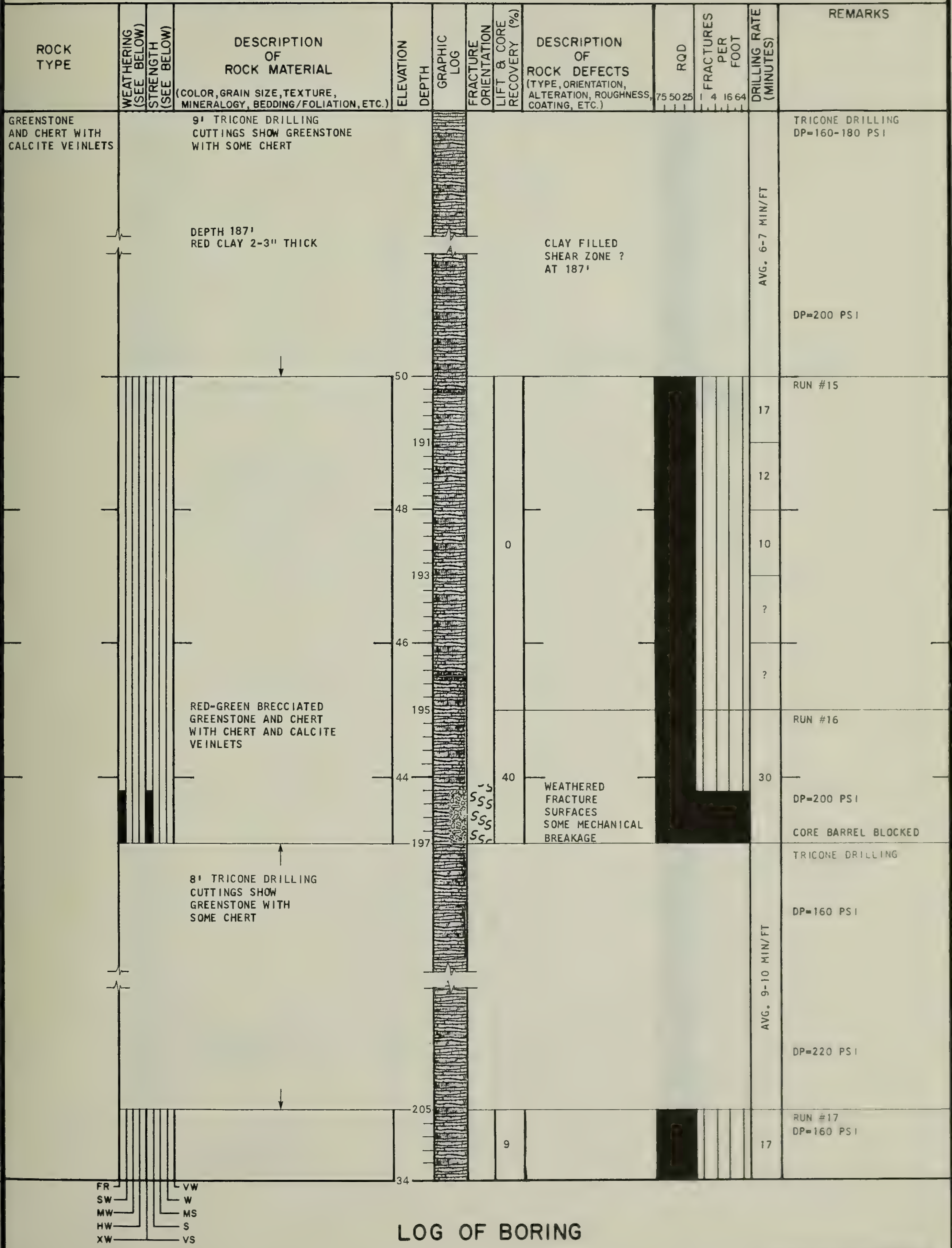
WEATHERING: FR, SW, MW, HW, XW
STRENGTH: VW, W, MS, S, VS

## LOG OF BORING

**DAMES & MOORE**

PLATE A-17/4

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 20
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION 34th. AVE. NEAR GEARY
ELEV. 240
PAGE 5 OF 7



GREENSTONE AND CHERT WITH CALCITE VEINLETS

9' TRICONE DRILLING CUTTINGS SHOW GREENSTONE WITH SOME CHERT

DEPTH 187'
RED CLAY 2-3" THICK

CLAY FILLED SHEAR ZONE ? AT 187'

RED-GREEN BRECCIATED GREENSTONE AND CHERT WITH CHERT AND CALCITE VEINLETS

WEATHERED FRACTURE SURFACES SOME MECHANICAL BREAKAGE

8' TRICONE DRILLING CUTTINGS SHOW GREENSTONE WITH SOME CHERT

TRICONE DRILLING
DP=160-180 PSI

DP=200 PSI

RUN #15

RUN #16

DP=200 PSI

CORE BARREL BLOCKED

TRICONE DRILLING

DP=160 PSI

DP=220 PSI

RUN #17
DP=160 PSI

LOG OF BORING

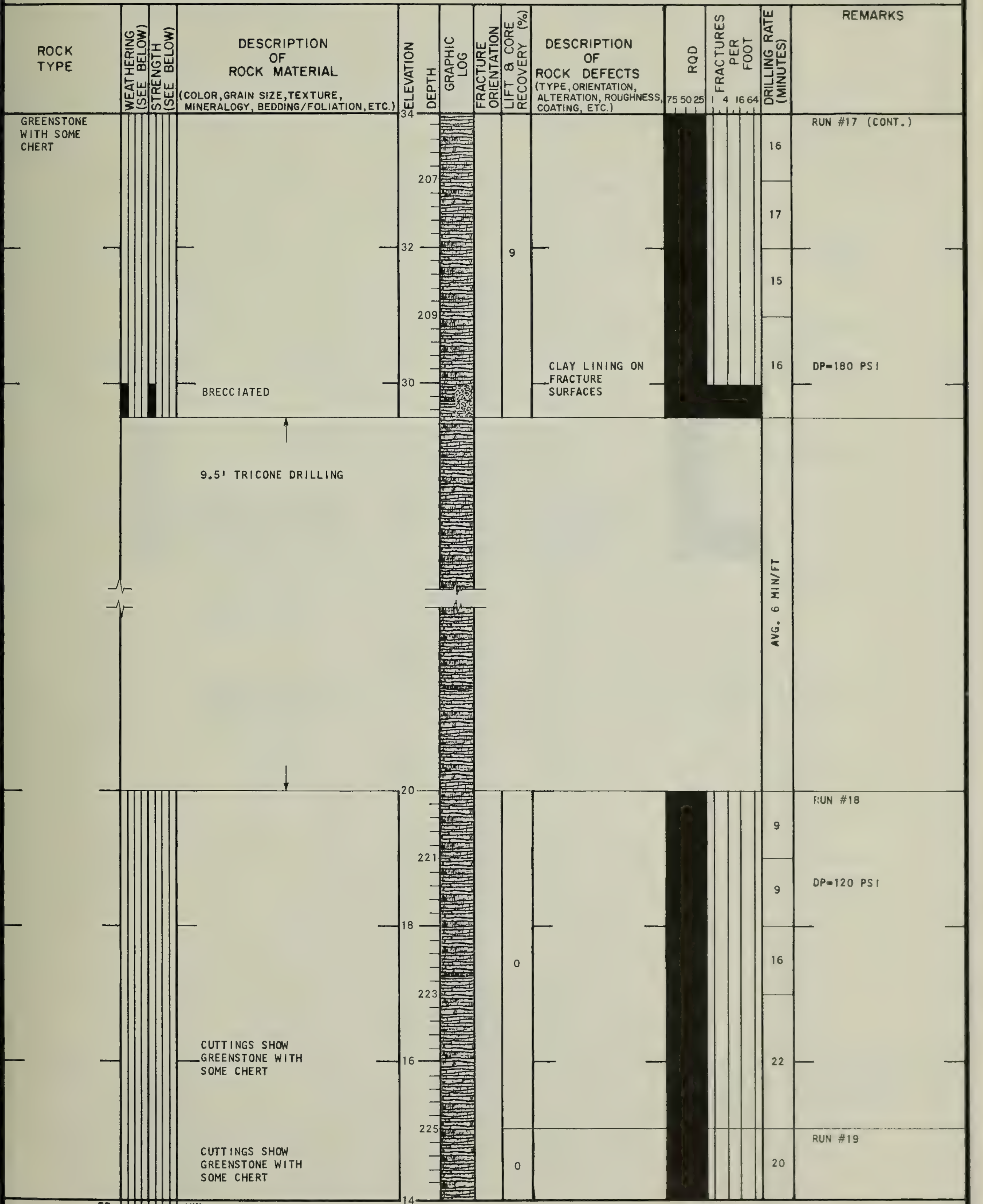
DAMES & MOORE

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 20

PROJECT: RICHMOND TRANSPORT SEWER

DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
ANGLE FROM HORIZONTAL 90°

LOCATION 34th. AVE. NEAR GEARY
ELEV. 240
PAGE 6 OF 7



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| GREENSTONE WITH SOME CHERT | | 34 | | 9 | | 16 | RUN #17 (CONT.) |
| | | | 207 | | | 17 | |
| | | 32 | | | | 15 | |
| | | | 209 | | | 16 | DP=180 PSI |
| | BRECCIATED | 30 | | | CLAY LINING ON FRACTURE SURFACES | | |
| | 9.5' TRICONE DRILLING | | | | | AVG. 6 MIN/FT | |
| | | 20 | | 0 | | 9 | RUN #18 |
| | | | 221 | | | 9 | DP=120 PSI |
| | | 18 | | | | 16 | |
| | CUTTINGS SHOW GREENSTONE WITH SOME CHERT | 16 | 223 | | | 22 | |
| | CUTTINGS SHOW GREENSTONE WITH SOME CHERT | | 225 | 0 | | 20 | RUN #19 |
| | | 14 | | | | | |

FR
SW
MW
HW
XW

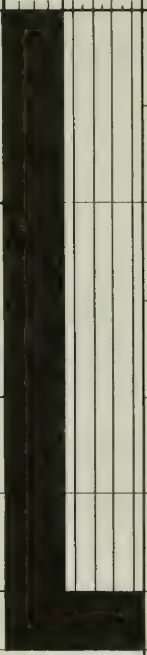
VW
W
MS
S
VS

## LOG OF BORING

DAMES & MOORE

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 20
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION 34th. AVE. NEAR GEARY
ELEV. 240
PAGE 7 OF 7

| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | FRACTURE ORIENTATION | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|---|
| GREENSTONE WITH SOME CHERT | | 14 | | | 0 | SHEAR ZONE? | 22 | RUN #19<br>DP=120-180 PSI |
| | | | 227 | | | | 23 | LOST ABOUT 25 GAL. OF DRILLING FLUID |
| | | 12 | | | 0 | | 25 | RUN #20<br>DP=260 PSI<br>DP=200 PSI |
| | | | 229 | | | | 22 | DP=220 PSI |
| | | 10 | | | | | 13 | DP=240 PSI |
| | RED-GREEN BRECCIATED GREENSTONE WITH CHERT VEINLETS, COARSE SAND SIZED BRECCIA | | 231 | S S S S S | 30 | HIGHLY SHEARED BRECCIATED FRACTURES WITH SLICKENSIDED SURFACES | 17 | RUN #21<br>DP=250 PSI |
| | | 8 | | | | | | |
| | 7.4' OF TRICONE DRILLING | | 233 | | | | 11 | TRICONE DRILLING |
| | | | | | | | 6 | |
| | CUTTINGS OF GREENSTONE WITH SOME CHERT AND CALCITE VEINLETS | 6 | | | | | 6 | |
| | | | 235 | | | | 6 | |
| | | 4 | | | | | 10 | |
| | | | 237 | | | | 13 | |
| | | 2 | | | | | 10 | |
| | | | 239 | | | | | |
| | | 0 | | | | | | TERMINATED BORING AT DEPTH 240' ELEVATION=0 |



WEATHERING (SEE BELOW): FR, SW, MW, HW, XW
STRENGTH (SEE BELOW): VW, W, MS, S, VS

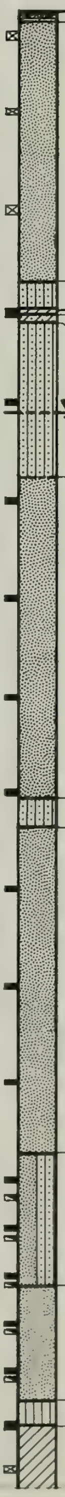
LOG OF BORING

DAMES & MOORE

## BORING 21

DRILLED 3/21-27/78

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | SHEAR STRENGTH TEST RESULTS, LABORATORY: TYPE OF TEST | LABORATORY: NORMAL OR CONFINING PRESSURE (PSF) | LABORATORY: PEAK SHEAR STRENGTH (PSF) | FIELD: TORVANE (PSF) | FIELD: PENETROMETER (PSF) | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT) or (HYD. PRESS., PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| +200 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | GRAB | | |
| +190 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | TW | 11 | 46 |
| +180 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | TW | 50 | 73 |
| +170 | | | | | | | | | | | | | | |
| | SA (38%) | 23 | 100 | | | | | | | | | U | 100 | 33 |
| +160 | | | | | | | | | | | | | | |
| | SA (9%) | 17 | 111 | | | | | | | | | U | 91 | 68/5" |
| +150 | | | | | | | | | | | | | | |
| | SA (6%) | 21 | 106 | | | | | | | | | U | 67 | 56/6" |
| +140 | | | | | | | | | | | | | | |
| | | 22 | 106 | | | | | | | | | U | 83 | 50/6" |
| +130 | | | | | | | | | | | | | | |
| | SA (6%) | 21 | 105 | | | | | | | | | U | 56 | 74 |
| +120 | | | | | | | | | | | | | | |
| | | 25 | 103 | | | | | | | | | U | 83 | 55/6" |
| +110 | | | | | | | | | | | | | | |
| | | 23 | 105 | | | | | | | | | U | 73 | 50/5" |
| +100 | | | | | | | | | | | | | | |
| | SA (7%) | 21 | 109 | | | | | | | | | U | 82 | 60/5" |
| +90 | | | | | | | | | | | | | | |
| | SA (4%) | 23 | 106 | | | | | | | | | U | 92 | 50/6" |
| +80 | | | | | | | | | | | | | | |
| | SA (12%) | 25 | 103 | | | DS/CD | 8500 | 5460 | | | | U<br>SPT | 92<br>100 | 48/6"<br>84/9" |
| +70 | PERM<br>SA (5%) | | | | | | | | | | | U<br>SPT | 87<br>91 | 58/5½"<br>75/5" |
| | SA (6%) | 24 | 102 | | | | | | | | | U<br>SPT | 92<br>100 | 56/6"<br>100/6" |
| +60 | SA (8%) | 24 | 107 | | | | | | | | | U<br>SPT | 73<br>100 | 50/5"<br>100/2" |
| | PERM<br>SA (5%) | | | | | | | | | | | U<br>SPT | 78<br>100 | 40/3"<br>100/4½" |
| +50 | | | | | | | | | | | | | | |
| | | 17 | 115 | | | UC | | 5120 | | | | U | 100 | 78 |
| | | 15 | 120 | | | UC | | 6970 | | | | U | 100 | 50/6" |



ELEVATION +195'

4" ASPHALT, 4" CONCRETE, BASECOURSE 2"

SP BROWN FINE SAND (DUNE SAND)

(DENSE)

(VERY DENSE)

SM LIGHT YELLOW-BROWN SILTY FINE SAND WITH IRON OXIDE STAIN (COLMA FORMATION)(DENSE)

(CLAYEY SILT LENSE)

SC DARK GRAY CLAYEY FINE SAND (DENSE)

SM LIGHT YELLOW-BROWN SLIGHTLY SILTY FINE SAND (VERY DENSE)

(GRADING LESS SILTY)

(WATER LEVEL 8/22/78)

SP LIGHT BROWN FINE SAND WITH TRACE OF SILT (VERY DENSE)

(GRADING FINER)

(GRADING REDDISH BROWN)

SM BROWN SILTY FINE SAND WITH ROCK FRAGMENTS (COLLUVIUM)(VERY DENSE)

SP DARK GRAY-BROWN FINE SAND (VERY DENSE)

SP/SM BROWN FINE SAND WITH FREQUENT LAYERS OF BROWN SILTY FINE SAND (VERY DENSE)

SP DARK BROWN FINE SAND (VERY DENSE)

(GRADING WITH TRACE OF SILT)

(GRADING WITH PARTIAL WEAK IRON OXIDE CEMENTATION)

ML LIGHT BROWN SANDY CLAYEY SILT WITH SOME ROCK FRAGMENTS (COLLUVIUM)(HARD)

CL DARK GRAY SILTY CLAY WITH TRACE OF SAND AND ROCK FRAGMENTS (COLLUVIUM)(HARD)
(GRADING BROWN)

OFFICIAL CITY GRADE.

3. REFER TO THE FOLLOWING GEOLOGIC LOGS FOR A MORE DETAILED DESCRIPTION OF THE BEDROCK.

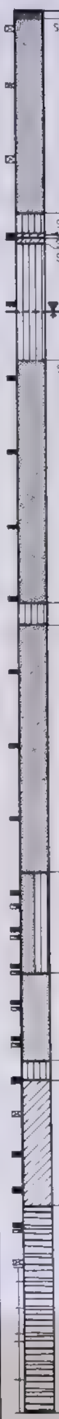
# LOG OF BORING

**DAMES & MOORE**

# BORING 21

DRILLED 3/21-27/78

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | SHEAR STRENGTH TEST RESULTS, LABORATORY: TYPE OF TEST | LABORATORY: NORMAL OR CONFINING PRESSURE (PSF) | LABORATORY: PEAK SHEAR STRENGTH (PSF) | FIELD: TORVANE (PSF) | FIELD: PENETROMETER (PSF) | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| +200 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | GRAB | | |
| +190 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | TW | 11 | 46 |
| +180 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | TW | 50 | 73 |
| +170 | | | | | | | | | | | | | | |
| | SA<br>(38 ) | 23 | 100 | | | | | | | | | U | 100 | 33 |
| +160 | | | | | | | | | | | | | | |
| | SA<br>(9 ) | 17 | 111 | | | | | | | | | U | 91 | 68/5' |
| +150 | | | | | | | | | | | | | | |
| | SA<br>(6 ) | 21 | 106 | | | | | | | | | U | 67 | 56/6 |
| +140 | | | | | | | | | | | | | | |
| | | 22 | 106 | | | | | | | | | U | 83 | 50/6" |
| +130 | | | | | | | | | | | | | | |
| | SA<br>(6 | 21 | 105 | | | | | | | | | U | 56 | 74 |
| +120 | | | | | | | | | | | | | | |
| | | 25 | 103 | | | | | | | | | U | 83 | 55/6" |
| +110 | | | | | | | | | | | | | | |
| | | 23 | 105 | | | | | | | | | U | 73 | 50/5" |
| +100 | | | | | | | | | | | | | | |
| | SA<br>(7 ) | 21 | 109 | | | | | | | | | U | 82 | 60/5 |
| +90 | | | | | | | | | | | | | | |
| | SA<br>(4½) | 23 | 106 | | | | | | | | | U | 92 | 50/6" |
| +80 | | | | | | | | | | | | | | |
| | SA<br>(12 ) | 25 | 103 | | | DS/CD | 8500 | 5460 | | | | U<br>SPT | 92<br>100 | 48/6"<br>84/9" |
| +70 | PERM<br>SA<br>(5½) | | | | | | | | | | | U<br>SPT | 87<br>91 | 58/5½"<br>75/5" |
| | SA<br>(6 ) | 24 | 102 | | | | | | | | | U<br>SPT | 92<br>100 | 56/6"<br>100/6" |
| +60 | SA<br>(8 ) | 24 | 107 | | | | | | | | | U<br>SPT | 73<br>100 | 50/5"<br>100/2" |
| | PERM<br>SA<br>(5 ) | | | | | | | | | | | U<br>SPT | 78<br>100 | 40/3"<br>100/4" |
| +50 | | 17 | 115 | | | UC | | 5120 | | | | U | 100 | 78 |
| | | 15 | 120 | | | UC | | 6970 | | | | U | 100 | 50/6' |
| +40 | | 17 | 115 | | | UC | | 4970 | | | | U | 100 | 60 |
| | | 16 | 120 | | | | | | | | | U | 100 | 71/9" |
| +30 | SA<br>(56. ) | 15 | 117 | | | DS/CD | 10 500 | 7080 | | | | U<br>SPT | 100<br>100 | 64/6"<br>100/3' |
| | | | | | | | | | | | | U | 67 | 100/6" |
| | | | | | | | | | | | 15<br>23<br>35 | NX | 85 | |
| +20 | | | | | | | | | | | 24<br>20<br>15<br>18 | NX | 100 | |
| | | | | | | | | | | | 30<br>17 | NX | 100 | |
| | | | | | | | | | | | 21<br>26<br>11 | NX | 100 | |
| | | | | | | | | | | | 12<br>13 | NX | 100 | |
| +10 | | | | | | | | | | | | | | |
| | | | | | | | | | | | 13<br>14<br>18<br>8<br>10<br>16 | NX | 95 | |
| 0 | | | | | | | | | | | | | | |



ELEVATION +195'

| | |
|---|---|
| SP | 4" ASPHALT, 4" CONCRETE, BASECOURSE 2"<br>BROWN FINE SAND (DUNE SAND)<br>(DENSE)<br>(VERY DENSE) |
| SM | LIGHT YELLOW-BROWN SILTY FINE SAND WITH IRON OXIDE STAIN (COLMA FORMATION)(DENSE)<br>(CLAYEY SILT LENSE) |
| SM | DARK GRAY CLAYEY FINE SAND (DENSE<br>LIGHT YELLOW-BROWN SLIGHTLY SILTY FINE SAND (VERY DENSE)<br>(GRADING LESS SILTY)<br>(WATER LEVEL 8/22/78) |
| SP | LIGHT BROWN FINE SAND WITH TRACE OF SILT (VERY DENSE)<br>(GRADING FINER)<br>(GRADING REDDISH BROWN) |
| SM | BROWN SILTY FINE SAND WITH ROCK FRAGMENTS (COLLUVIUM)(VERY DENSE) |
| SP | DARK GRAY-BROWN FINE SAND (VERY DENSE) |
| SP/SM | BROWN FINE SAND WITH FREQUENT LAYERS OF BROWN SILTY FINE SAND (VERY DENSE) |
| SP | DARK BROWN FINE SAND (VERY DENSE)<br>(GRADING WITH TRACE OF SILT)<br>(GRADING WITH PARTIAL WEAK IRON OXIDE CEMENTATION) |
| ML | LIGHT BROWN SANDY CLAYEY SILT WITH SOME ROCK FRAGMENTS (COLLUVIUM)(HARD) |
| CL | DARK GRAY SILTY CLAY WITH TRACE OF SAND AND ROCK FRAGMENTS (COLLUVIUM)(HARD)<br>(GRADING BROWN) |
| | YELLOW-BROWN GRAYWACKE WITH GRAY CLAY-FILLED SEAMS (EXTREMELY WEATHERED)(FRANCISCAN BEDROCK)<br>(GRADING HIGHLY WEATHERED BROWN-GRAY)<br>(GRADING MODERATELY WEATHERED, IRON OXIDE STAINED JOINTS)<br>(BECOMING SLIGHTLY WEATHERED, STRONG WITH THIN SHEARED SHALE INTERBEDS, MODERATELY TO HIGHLY FRACTURED RQD = 0) |
| | (BECOMING GRAY, MODERATELY WEATHERED, MODERATELY STRONG, RQD = 0) |

NOTES

1. SAMPLING RESISTANCE:
   SPT DRIVEN BY 140 POUND HAMMER FALLING 30"
   U AND TW DRIVEN BY 350 POUND SLIPJARS FALLING 15"
2. ELEVATIONS REFER TO S.F. DATUM ARE BASED ON OFFICIAL CITY GRADE.
3. REFER TO THE FOLLOWING GEOLOGIC LOGS FOR A MORE DETAILED DESCRIPTION OF THE BEDROCK.

## LOG OF BORING

**DAMES & MOORE**

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)

BORING NO. 21

PROJECT: RICHMOND TRANSPORT SEWER

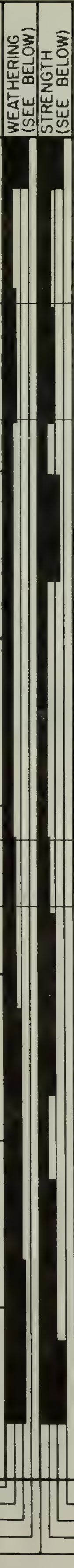
ANGLE FROM HORIZONTAL 90°

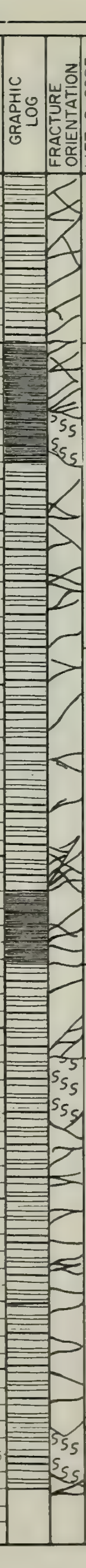
DRILLING METHOD: NX CORING WITH REVERT SLURRY

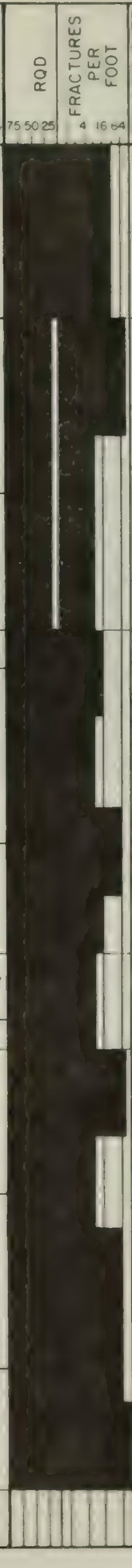
LOCATION CALIF. STREET NEAR 32nd AVE.

ELEV. 195

PAGE 1 OF 2







| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| GRAYWACKE | MEDIUM BROWNISH GRAY, IRON OXIDE STAINING IN FRACTURE, FINE GRAINED, THIN BEDDED, FEW CALCITE VEINLETS. | 24 | | | MODERATELY FRACTURED, MOSTLY PARALLEL TO BEDDING. | 15 | RUN #1<br>DP = 80 PSI |
| | | | 172 | 85 | | | |
| | | | | | | 23 | DP = 100 PSI |
| SHALE | MEDIUM TO VERY DARK GRAY. VERY FINE GRAINED. THIN BEDDED. | 22 | | | HIGHLY FRACTURED WITH CLAY FILLING FRACTURES, MOSTLY PARALLEL TO BEDDING. CLAY SEAMS SLAKE READILY | 36 | RUN #2<br>DP = 0 PSI |
| | | | 174 | | | | |
| GRAYWACKE | MEDIUM BROWN-GRAY, MEDIUM GRAINED, MEDIUM BEDDED, CALCITE VEINLETS COMMON. | | | 100 | | 24 | DP = 80 PSI |
| | | 20 | | | | | |
| | | | | | | 20 | DP = 120 PSI |
| | CP=4,400 PSI - D<br>CP=1,900 PSI - A | | | | | | |
| | | | 176 | | | 15 | DP = 200 PSI |
| | CP=17,400 PSI - D | | | | MODERATELY FRACTURED, RANDOMLY ORIENTED | | |
| | | 18 | | | | 18 | RUN #3<br>DP = 100 PSI |
| | | | | | DOES NOT SLAKE | | |
| | | | 178 | 100 | | 20 | DP = 120 PSI |
| | | 16 | | | | 17 | DP = 140 PSI |
| SHALE | DARK GRAY, THIN BEDDED. | | | | DOES NOT SLAKE | | |
| | | | 180 | | | 21 | (BLOCKED ?) |
| GRAYWACKE | MEDIUM TO DARK GRAY, MEDIUM GRAINED, FEW CALCITE VEINLETS | | | 100 | MODERATELY FRACTURED, MOSTLY CLEAN | 26 | RUN #4<br>2'-3' RAPID DROP<br>LOSS OF WATER |
| | | 14 | | | | | |
| | LIGHT TO MEDIUM GRAY, FINE GRAINED, NUMEROUS SMALL CLASTS OF BLACK SOFT ORGANICS | | | | HIGHLY FRACTURED SLIGHT SUSCEPTIBILITY TO SLAKING, SLOW | 11 | RUN #5<br>DP = 0 PSI |
| | | | 182 | | | | |
| | INTERBEDDED SHALE AND GRAYWACKE; THIN AND MEDIUM THICK BEDS | | | | | 12 | DP = 100 PSI |
| | | 12 | | | | | |
| | | | 184 | 100 | | 13 | SOFTER ZONE |
| | CP=3,700 PSI - D | | | | | | |
| | | | | | | 13 | LOSS OF WATER |
| | | 10 | | | | | |
| | | | 186 | | SHEAR ZONE | 14 | |
| | | | | | | | RUN #6<br>(SEE NEXT PAGE) |
| | | 8 | | | | | |

## LOG OF BORING

**DAMES & MOORE**

PLATE A-IU/1

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)

BORING NO. 21

PROJECT: RICHMOND TRANSPORT SEWER

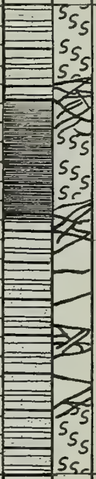
ANGLE FROM HORIZONTAL 90°

DRILLING METHOD: NX CORING WITH REVERT SLURRY

LOCATION CALIF. STREET NEAR 32nd. AVE.

ELEV. 195

PAGE 2 OF 2



| ROCK TYPE | WEATHERING (SEE BELOW) | STRENGTH (SEE BELOW) | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | GRAPHIC LOG | FRACTURE ORIENTATION | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | RQD 75 50 25 | FRACTURES PER FOOT 1 4 16 64 | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 186 | | | | | | | | (SEE PREVIOUS PAGE) |
| GRAYWACKE | | | MEDIUM GRAY AND GRAY-BROWN FINE GRAINED SAND MATERIAL WITH SMALL POCKETS OF SOFT BLACK ORGANICS | 8 | | | | | HIGHLY FRACTURED TO SHEARED. MOST FRACTURES HEALED. DOES NOT SLAKE | | | 18 | RUN #6<br>DP = 0 PSI<br>LOSS OF WATER |
| SHALE | | | DARK GRAY TO BLACK VERY FINE GRAINED. FEW CALCITE VEINLETS FRACTURES MOSTLY CLAY COATED<br>CP=1,500 PSI - D | | 188 | | | | HIGHLY FRACTURED DOES NOT SLAKE<br>HIGHLY SHEARED SLAKES READILY | | | 9 | DP = 100 PSI |
| GRAYWACKE | | | MEDIUM TO DARK BLUE-GRAY FINE GRAINED SAND MATERIAL FEW LARGE CALCITE VEINLETS, VERY FEW SMALL POCKETS OF ORGANICS.<br>CP=6,600 PSI - D | 6<br>4 | 190 | | | 95 | MODERATELY FRACTURED<br>HIGHLY FRACTURED<br>HIGHLY SHEARED. MODERATE SUSCEPTIBILITY TO SLAKING SLICKENSIDES | | | 10<br>10<br>16 | LOSS OF WATER<br>DP = 0 PSI<br>LOSS OF WATER |
| | | | | | 192 | | | | | | | | END OF BORING 21<br>ELEVATION 3.8' |

FR
SW
MW
HW
XW

VW
W
MS
S
VS

LOG OF BORING

**DAMES & MOORE**

## BORING 22
DRILLED 3/23-4/3/78

| | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS | | SHEAR STRENGTH TEST RESULTS | | | | | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD.PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | LABORATORY | | | FIELD | | | | | |
| | | | | LIQUID LIMIT | PLASTIC LIMIT | TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | TORVANE (PSF) | PENETROMETER (PSF) | | | | |
| +280 | | | | | | | | | | | | | | |
| +270 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | U | 78 | 56 |
| +260 | | | | | | | | | | | | | | |
| +250 | | | | | | | | | | | | U | 78 | 120 |
| +240 | | | | | | | | | | | | | | |
| +230 | | | | | | | | | | | | U | 80 | 50<br>4" |
| +220 | | | | | | | | | | | | U | 76 | 55<br>4.5" |
| +210 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | U | 78 | 90 |
| | SA (13%) | 18 | 110 | | | | | | | | | U | 83 | 63<br>6" |
| +200 | | | | | | | | | | | | | | |
| | PERM | | | | | | | | | | 20<br>30<br>23<br>22<br>13 | NX<br>NX<br>NX | 67<br>80<br>100 | |
| +20 | | | | | | | | | | | 10<br>8<br>6 | NX | 100 | |
| | | | | | | | | | | | 10<br>14<br>11<br>11<br>11<br>11 | NX<br>NX | 100<br>70 | |
| +10 | | | | | | TX/CU<br>TX/CU<br>TX/CU | 12,960<br>12,960<br>12,960 | 8830<br>2300<br>1630 | | | 10<br>9<br>10<br>10<br>10<br>10<br>10<br>10<br>10<br>10<br>12 | NX<br>NX | 100<br>100 | |
| 0 | | | | | | TX/CU<br>TX/CU | 12,960<br>12,960 | 2930<br>2980 | | | 12<br>12<br>15<br>15 | NX | 100 | |
| -10 | | | | | | | | | | | | | | |

ELEVATION +275'

3" ASPHALT PAVEMENT OVER 8" CONCRETE

SP — BROWN FINE SAND (DUNE SAND) (DENSE)

(VERY DENSE)

(GRADING SLIGHTLY SILTY)

SM/ML — DARK BROWN VERY SILTY FINE SAND, NON-PLASTIC (VERY DENSE) (COLMA FORMATION)

SM — BROWN TO YELLOWISH-BROWN SLIGHTLY SILTY FINE SAND (VERY DENSE)

(GREENSTONE INCLUSION, BRECCIATED, FRESH, STRONG)

(GREENSTONE INCLUSION, HIGHLY BRECCIATED, FRESH)

(GRAYWACKE INCLUSION, MASSIVE, FRESH, VERY STRONG)

(SHEARED SHALE MATRIX GRADING WITH GRAYWACKE INCLUSIONS)

(GRAYWACKE INCLUSION, HIGHLY BRECCIATED)

(SHEARED SHALE MATRIX GRADING WITH SERPENTINE, HIGH SUSCEPTIBILITY TO SLAKING)

(LIGHT GREEN SERPENTINE INCLUSION, HIGHLY SHEARED, SLICKENSIDED, FRESH, VERY WEAK)

NOTES:

1. SAMPLING RESISTANCE:
   U SAMPLER DRIVEN BY 325 POUND SLIPJARS FALLING 16"
2. ELEVATIONS REFER TO S.F. DATUM AND BASED ON OFFICIAL CITY GRADE.
3. REFER TO FOLLOWING GEOLOGIC LOGS FOR A MORE DETAILED DESCRIPTION OF THE BEDROCK

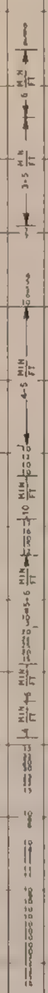
# LOG OF BORING

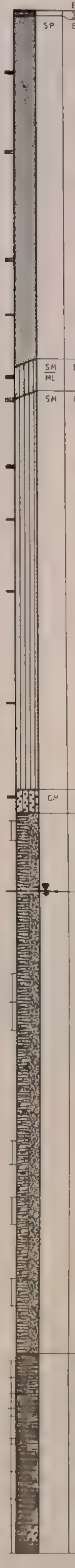
**DAMES & MOORE**

## BORING 22
DRILLED 3/23-4/3/78

ELEVATION IN FEET

| OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | SHEAR STRENGTH TEST RESULTS, LABORATORY: TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | FIELD: TORVANE (PSF) | FIELD: PENETROMETER (PSF) | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT) or (HYD PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | U | 78 | 56 |
| | | | | | | | | | | | U | 78 | 120 |
| | | | | | | | | | | | U | 80 | 50/4" |
| | | | | | | | | | | | U | 76 | 55/45" |
| | | | | | | | | | | | U | 78 | 90 |
| SA (13') | 18 | 110 | | | | | | | | | U | 83 | 63/6" |
| PERM SA (21') | 18 | 114 | | | | | | | | | U | 78 | 62 |
| SA (10 ) | 22 | 95 | | | | | | | | | U | 50 | 75/6 |
| SA (8 ) | 26 | 96 | | | | | | | | | U | 50 | 58/6" |
| SA (17 ) | 20 | 109 | | | | | | | | | U | 50 | 85/6" |
| | 14 | 129 | | | | | | | | | U | 100 | 60 |
| | | | | | | | | | | | NX | 22 | |
| | | | | | | | | | | | NX | 0 | |
| | | | | | | | | | | | NX | 9 | |
| | | | | | | | | | | | NX | 18 | |
| | | | | | | | | | | | NX | 16 | |
| | | | | | | | | | | | NX | 30 | |
| | | | | | | | | | | | NX | 65 | |
| | | | | | | | | | | | NX | 67 | |
| | | | | | | | | | | | NX | 80 | |
| | | | | | | | | | | | NX | 100 | |
| | | | | | | | | | | | NX | 100 | |
| | | | | | | | | | | | NX | 100 | |
| | | | | | | | | | | | NX | 70 | |
| | | | | | TX/CU | 12,960 | 8830 | | | | NX | 100 | |
| | | | | | TX/CU | 12,960 | 2300 | | | | | | |
| | | | | | TX/CU | 12,960 | 1630 | | | | NX | 100 | |
| | | | | | TX/CU | 12,960 | 2930 | | | | NX | 100 | |
| | | | | | TX/CU | 12,960 | 2980 | | | | | | |





ELEVATION +275'

3" ASPHALT PAVEMENT OVER 8" CONCRETE

BROWN FINE SAND (DUNE SAND) (DENSE)

(VERY DENSE)

(GRADING SLIGHTLY SILTY)

DARK BROWN VERY SILTY FINE SAND, NON-PLASTIC (VERY DENSE) (COLMA FORMATION)

BROWN TO YELLOWISH-BROWN SLIGHTLY SILTY FINE SAND (VERY DENSE)

(GRADING SLIGHTLY FINER, MORE SILTY)

(THIN GRAVELLY LAYER, COLLUVIUM)
(GRADING SLIGHTLY COARSER, LESS SILTY)

(BECOMING REDDISH BROWN, SILTIER)

DARK REDDISH-BROWN SILTY COARSE SANDY GRAVEL, COMPOSED OF ANGULAR CHERT FRAGMENTS (COLLUVIUM)

RED GREENSTONE WITH SOME CHERT, MINOR QUARTZ VEINS, BRECCIATED, HIGHLY WEATHERED, MODERATELY STRONG, (RQD = 0%)
(GREENSTONE FROM ELEV. +31 TO +130 MAY BE SINGLE LARGE INCLUSION IN A SHEARED SHALE MELANGE)

(WATER LEVEL 8/22/78)

(GRADING MODERATELY WEATHERED)

(GRADING STRONG, RQD = 0 TO 20

BLACK SHEARED SHALE WITH BRECCIATED GREENSTONE INCLUSIONS, FRESH, WEAK (MELANGE)
(GREENSTONE INCLUSION, BRECCIATED, FRESH, STRONG)

(GREENSTONE INCLUSION, HIGHLY BRECCIATED, FRESH)

(GRAYWACKE INCLUSION, MASSIVE, FRESH, VERY STRONG)
(SHEARED SHALE MATRIX GRADING WITH GRAYWACKE INCLUSIONS)

(GRAYWACKE INCLUSION, HIGHLY BRECCIATED)
(SHEARED SHALE MATRIX GRADING WITH SERPENTINE, HIGH SUSCEPTIBILITY TO SLAKING)

(LIGHT GREEN SERPENTINE INCLUSION HIGHLY SHEARED SLICKENSIDED, FRESH VERY WEAK)

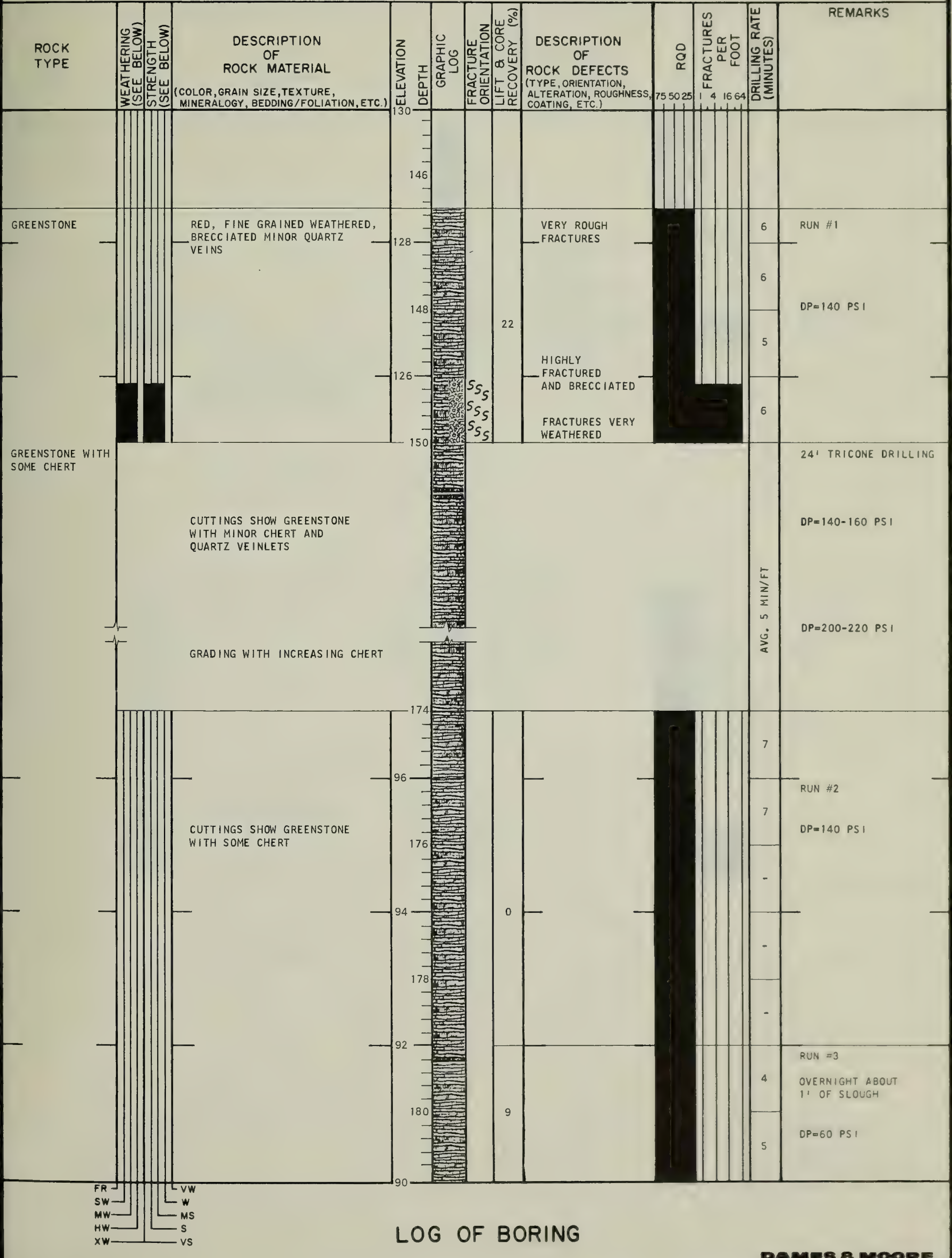
NOTES:
1. SAMPLING RESISTANCE:
   U SAMPLER DRIVEN BY 325 POUND SLIPJARS FALLING 16"
2. ELEVATIONS REFER TO S.F. DATUM AND BASED ON OFFICIAL CITY GRADE.
3. REFER TO FOLLOWING GEOLOGIC LOGS FOR A MORE DETAILED DESCRIPTION OF THE BEDROCK

# LOG OF BORING

DAMES & MOORE

PLATE A-IV

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 22
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION 41st. AVE. NEAR GEARY
ELEV. 275
PAGE 1 OF 6



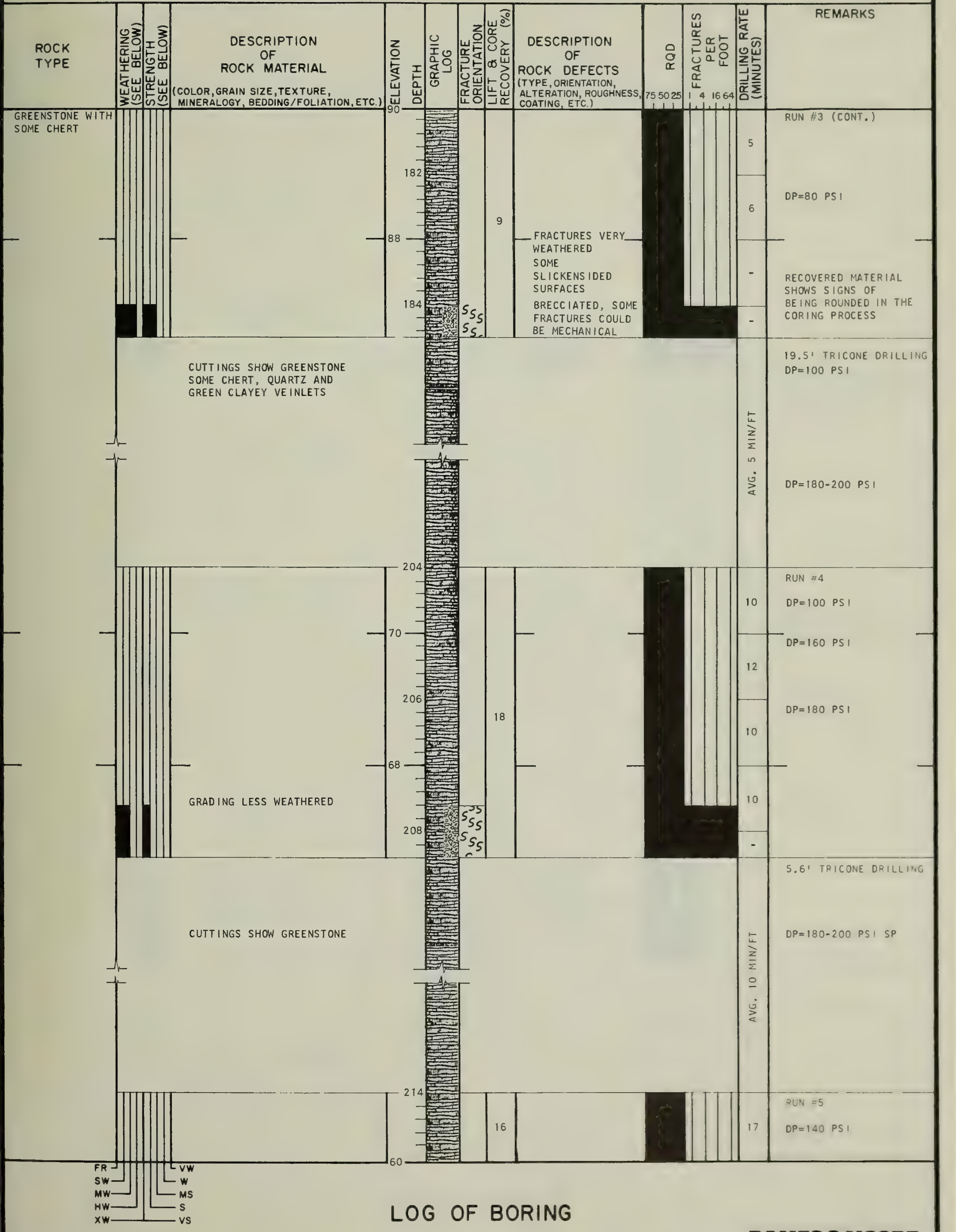
| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|
| GREENSTONE | RED, FINE GRAINED WEATHERED, BRECCIATED MINOR QUARTZ VEINS | 22 | VERY ROUGH FRACTURES<br>HIGHLY FRACTURED AND BRECCIATED<br>FRACTURES VERY WEATHERED | 6<br>6<br>5<br>6 | RUN #1<br>DP=140 PSI |
| GREENSTONE WITH SOME CHERT | CUTTINGS SHOW GREENSTONE WITH MINOR CHERT AND QUARTZ VEINLETS<br>GRADING WITH INCREASING CHERT | | | AVG. 5 MIN/FT | 24' TRICONE DRILLING<br>DP=140-160 PSI<br>DP=200-220 PSI |
| | CUTTINGS SHOW GREENSTONE WITH SOME CHERT | 0 | | 7<br>7<br>-<br>-<br>- | RUN #2<br>DP=140 PSI |
| | | 9 | | 4<br>5 | RUN #3<br>OVERNIGHT ABOUT 1' OF SLOUGH<br>DP=60 PSI |

LOG OF BORING

DAMES & MOORE

PLATE A-IV/1

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 22
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION 41st. AVE. NEAR GEARY
ELEV. 275
PAGE 2 OF 6



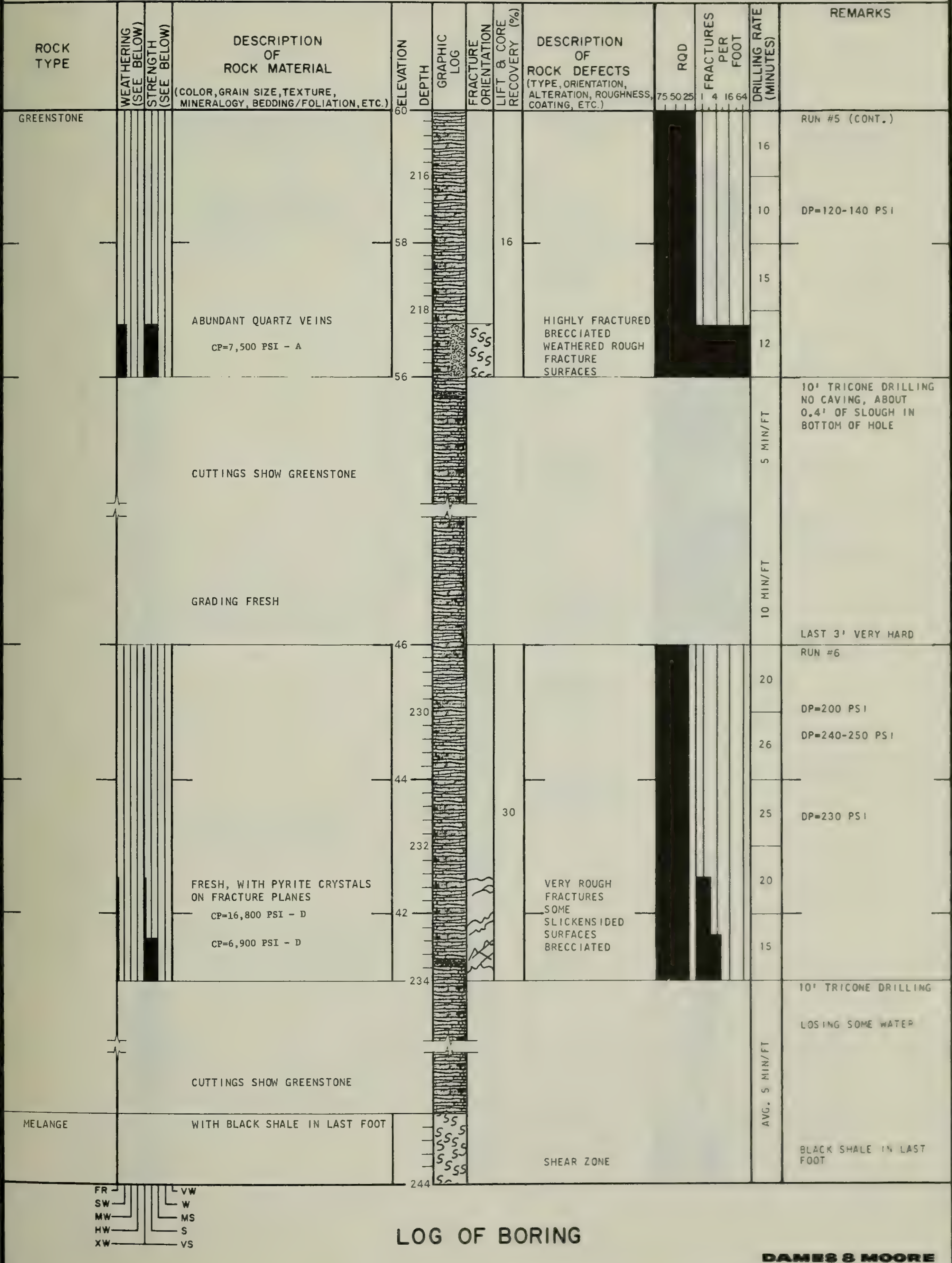
| Rock type | Description of rock material | Depth | Lift & core recovery (%) | Description of rock defects | Drilling rate (minutes) | Remarks |
|---|---|---|---|---|---|---|
| GREENSTONE WITH SOME CHERT | | 181–185 | 9 | FRACTURES VERY WEATHERED<br>SOME SLICKENSIDED SURFACES<br>BRECCIATED, SOME FRACTURES COULD BE MECHANICAL | 5<br>6<br>-<br>- | RUN #3 (CONT.)<br>DP=80 PSI<br>RECOVERED MATERIAL SHOWS SIGNS OF BEING ROUNDED IN THE CORING PROCESS |
| | CUTTINGS SHOW GREENSTONE SOME CHERT, QUARTZ AND GREEN CLAYEY VEINLETS | 185–204 | | | AVG. 5 MIN/FT | 19.5' TRICONE DRILLING<br>DP=100 PSI<br>DP=180-200 PSI |
| | GRADING LESS WEATHERED | 204–208.4 | 18 | | 10<br>12<br>10<br>10<br>- | RUN #4<br>DP=100 PSI<br>DP=160 PSI<br>DP=180 PSI |
| | CUTTINGS SHOW GREENSTONE | 208.4–214 | | | AVG. 10 MIN/FT | 5.6' TRICONE DRILLING<br>DP=180-200 PSI SP |
| | | 214–215 | 16 | | 17 | RUN #5<br>DP=140 PSI |

LOG OF BORING

**DAMES & MOORE**

PLATE A-IV/2

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 22
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION
ELEV. 275
PAGE 3 OF 6



GREENSTONE

ABUNDANT QUARTZ VEINS

CP=7,500 PSI – A

HIGHLY FRACTURED BRECCIATED WEATHERED ROUGH FRACTURE SURFACES

RUN #5 (CONT.)

DP=120-140 PSI

CUTTINGS SHOW GREENSTONE

GRADING FRESH

10' TRICONE DRILLING NO CAVING, ABOUT 0.4' OF SLOUGH IN BOTTOM OF HOLE

LAST 3' VERY HARD

RUN #6

DP=200 PSI

DP=240-250 PSI

DP=230 PSI

FRESH, WITH PYRITE CRYSTALS ON FRACTURE PLANES

CP=16,800 PSI – D

CP=6,900 PSI – D

VERY ROUGH FRACTURES SOME SLICKENSIDED SURFACES BRECCIATED

CUTTINGS SHOW GREENSTONE

10' TRICONE DRILLING

LOSING SOME WATER

MELANGE

WITH BLACK SHALE IN LAST FOOT

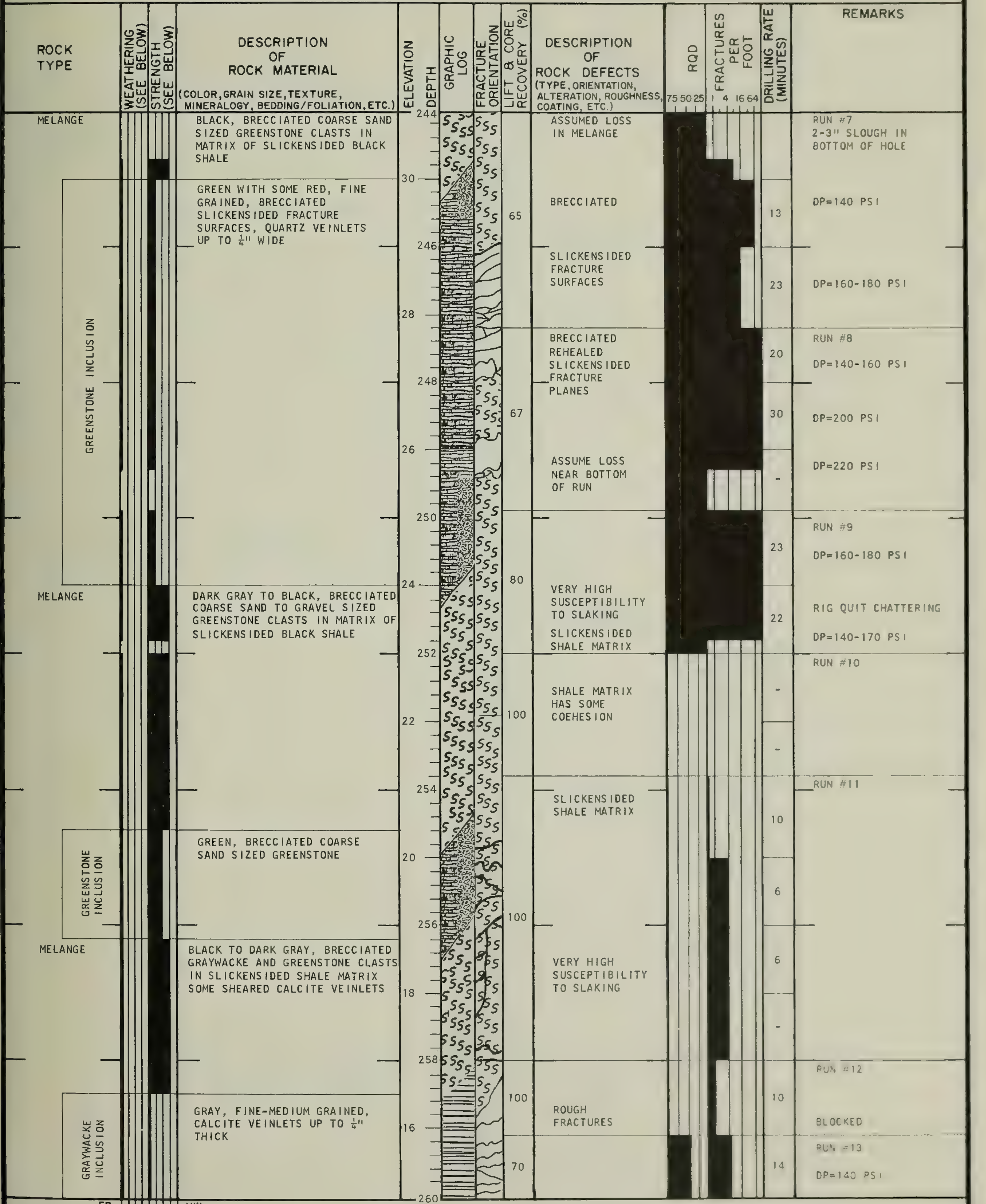
SHEAR ZONE

BLACK SHALE IN LAST FOOT

## LOG OF BORING

**DAMES & MOORE**

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 22
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION 41st. AVE. NEAR GEARY
ELEV. 275
PAGE 4 OF 6



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| MELANGE | BLACK, BRECCIATED COARSE SAND SIZED GREENSTONE CLASTS IN MATRIX OF SLICKENSIDED BLACK SHALE |  | 244 |  | ASSUMED LOSS IN MELANGE |  | RUN #7<br>2-3" SLOUGH IN BOTTOM OF HOLE |
| GREENSTONE INCLUSION | GREEN WITH SOME RED, FINE GRAINED, BRECCIATED SLICKENSIDED FRACTURE SURFACES, QUARTZ VEINLETS UP TO $\frac{1}{4}$" WIDE | 30 |  | 65 | BRECCIATED | 13 | DP=140 PSI |
|  |  |  | 246 |  | SLICKENSIDED FRACTURE SURFACES | 23 | DP=160-180 PSI |
|  |  | 28 |  |  | BRECCIATED REHEALED SLICKENSIDED FRACTURE PLANES | 20 | RUN #8<br>DP=140-160 PSI |
|  |  |  | 248 | 67 |  | 30 | DP=200 PSI |
|  |  | 26 |  |  | ASSUME LOSS NEAR BOTTOM OF RUN | - | DP=220 PSI |
|  |  |  | 250 | 80 |  | 23 | RUN #9<br>DP=160-180 PSI |
| MELANGE | DARK GRAY TO BLACK, BRECCIATED COARSE SAND TO GRAVEL SIZED GREENSTONE CLASTS IN MATRIX OF SLICKENSIDED BLACK SHALE | 24 |  |  | VERY HIGH SUSCEPTIBILITY TO SLAKING<br>SLICKENSIDED SHALE MATRIX | 22 | RIG QUIT CHATTERING<br>DP=140-170 PSI |
|  |  |  | 252 | 100 | SHALE MATRIX HAS SOME COEHESION | - | RUN #10 |
|  |  | 22 |  |  |  | - |  |
| GREENSTONE INCLUSION | GREEN, BRECCIATED COARSE SAND SIZED GREENSTONE |  | 254 |  | SLICKENSIDED SHALE MATRIX | 10 | RUN #11 |
|  |  | 20 |  | 100 |  | 6 |  |
| MELANGE | BLACK TO DARK GRAY, BRECCIATED GRAYWACKE AND GREENSTONE CLASTS IN SLICKENSIDED SHALE MATRIX SOME SHEARED CALCITE VEINLETS |  | 256 |  | VERY HIGH SUSCEPTIBILITY TO SLAKING | 6 |  |
|  |  | 18 |  |  |  | - |  |
| GRAYWACKE INCLUSION | GRAY, FINE-MEDIUM GRAINED, CALCITE VEINLETS UP TO $\frac{1}{4}$" THICK |  | 258 | 100 | ROUGH FRACTURES | 10 | RUN #12<br>BLOCKED |
|  |  | 16 |  | 70 |  | 14 | RUN #13<br>DP=140 PSI |
|  |  |  | 260 |  |  |  |  |

| WEATHERING | STRENGTH |
|---|---|
| FR | VW |
| SW | W |
| MW | MS |
| HW | S |
| XW | VS |

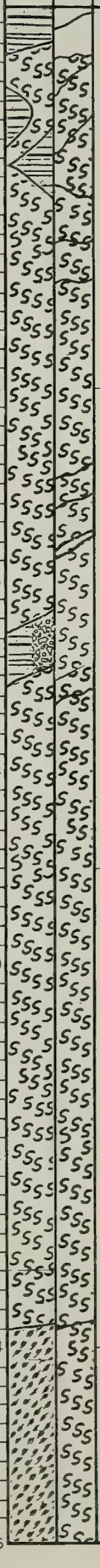
LOG OF BORING

**DAMES & MOORE**

PLATE A-IV/4

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 22
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION 41st. AVE. NEAR GEARY
ELEV. 275
PAGE 5 OF 6

| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| GRAYWACKE INCLUSION<br>MELANGE | | | 260 | | | 11 | RUN #13 (CONT.) |
| | WITH GRAYWACKE INCLUSIONS | 14 | | | | 11 | |
| | | | 262 | 70 | HIGH SUSCEPTIBILITY TO SLAKING | 11 | |
| | | 12 | | | ASSUME LOSS IN MELANGE | 11 | |
| | | | 264 | | | 10 | RUN #14 |
| | | 10 | | | | 9 | |
| GRAYWACKE INCLUSION | HIGHLY BRECCIATED | | 266 | 100 | | 10 | DP=180-200 PSI |
| MELANGE | MELANGE MATRIX, SERPENTINE RICH CLAY | 8 | | | HIGH SUSCEPTIBILITY TO SLAKING | 10 | |
| | | | 268 | | | 10 | |
| | | 6 | | | | 10 | RUN #15<br>DP=WEIGHT OF RODS |
| | | | 270 | | CLAY MATRIX HAS SOME COHESION | 10 | |
| | | 4 | | 100 | | 10 | |
| | INCREASING IN SERPENTINE CONTENT | | 272 | | | 10 | |
| | | 2 | | | | 10 | DP=100 PSI |
| SERPENTINE INCLUSION | LIGHT GREEN-HIGHLY SHEARED WITH MINOR SAND SIZED BRECCIA CLASTS OF BLACK SERPENTINE | | 274 | 100 | HIGHLY SLICKENSIDED VERY WEAK WHEN WET | 12 | RUN #16 |
| | | 0 | | | MODERATE SUSCEPTIBILITY TO SLAKING | 12 | |
| | | | 276 | | | | |



WEATHERING (SEE BELOW): FR, SW, MW, HW, XW
STRENGTH (SEE BELOW): VW, W, MS, S, VS
RQD: 75 50 25
FRACTURES PER FOOT: 1 4 16 64

# LOG OF BORING

**DAMES & MOORE**

PLATE A-IV/5

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 22

PROJECT: RICHMOND TRANSPORT SEWER

DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
ANGLE FROM HORIZONTAL 90°

LOCATION 41st. AVE. NEAR GEARY
ELEV. 275
PAGE 6 OF 6

| ROCK TYPE | WEATHERING (SEE BELOW) | STRENGTH (SEE BELOW) | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | GRAPHIC LOG | FRACTURE ORIENTATION | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | RQD 75 50 25 | FRACTURES PER FOOT 1 4 16 64 | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SERPENTINE INCLUSION | | | | | 276 | | | | VERY HIGH SUSCEPTIBILITY TO SLAKING | | | 12 | RUN #16 (CONT.) |
| MELANGE | | | GRAY BRECCIATED SAND SIZED GRAYWACKE, GREENSTONE AND SERPENTINE CLASTS IN MATRIX OF SERPENTINE RICH CLAY | -2 | | | | 100 | | | | 15 | |
| | | | | | 278 | | | | CLAY MATRIX HAS SOME COHESION | | | 15 | DP=140 PSI |
| | | | | -3.8 | | | | | | | | | TERMINATED BORING AT ELEVATION -3.8' DEPTH 278.8' |

FR SW MW HW XW

VW W MS S VS

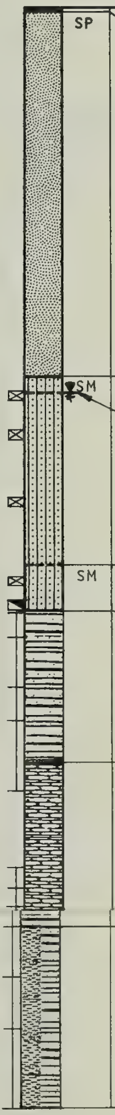
# LOG OF BORING

**DAMES & MOORE**

PLATE A-IV/6

# BORING 23
DRILLED 4/4-20/78

| Elevation | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | SHEAR STRENGTH TEST RESULTS, LABORATORY: TYPE OF TEST | SHEAR STRENGTH TEST RESULTS, LABORATORY: NORMAL OR CONFINING PRESSURE (PSF) | SHEAR STRENGTH TEST RESULTS, LABORATORY: PEAK SHEAR STRENGTH (PSF) | SHEAR STRENGTH TEST RESULTS, FIELD: TORVANE (PSF) | SHEAR STRENGTH TEST RESULTS, FIELD: PENETROMETER (PSF) | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT) or (HYD. PRESS., PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| +260 | | | | | | | | | | | | | | |
| +250 | | | | | | | | | | | | | | |
| +240 | | | | | | | | | | | | | | |
| +230 | | | | | | | | | | | | | | |
| +220 | | | | | | | | | | | | | | |
| +210 | | | | | | | | | | | | GRAB<br>GRAB | | |
| +200 | | | | | | | | | | | | GRAB | | |
| +190 | | | | | | | | | | | 1<br>2<br>4<br>4 | SPT<br>NX<br>NX | 100<br>70<br>10 | 60/6" |
| +180 | | | | | | | | | | | 3-4 MIN/FT | NX<br>NX | 10<br>0 | |
| +170 | | | | | | | | | | | | | | |
| +160 | | | | | | | | | | | 2<br>3<br>5<br>5<br>5<br>7<br>10<br>8 | NX<br>NX | 0<br>0 | |
| +20 | | | | | | | | | | | 12<br>12<br>15<br>15 | NX<br>NX | 100<br>95 | |
| +10 | | | | | | | | | | | 15<br>16<br>16<br>18<br>16<br>15<br>15<br>14 | NX | 3 | |
| 0 | | | | | | | | | | | | | | |



ELEVATION +251'

2" ASPHALTIC PAVEMENT

BROWN TO YELLOW-BROWN FINE SAND (DUNE SAND)

BROWN AND RED-BROWN SILTY FINE SAND (COLMA FORMATION)

(WATER LEVEL 8/22/78)

BROWN AND GRAY SILTY FINE SAND WITH SOME FINE CHERT FRAGMENTS (COLLUVIUM)
(GRADING WITH WEATHERED SANDSTONE FRAGMENTS)

GRAY-BROWN FINE TO MEDIUM GRAINED GRAYWACKE MODERATELY WEATHERED, MODERATELY STRONG, HIGHLY HIGHLY FRACTURED. IRON STAINED JOINTS FILLED WITH A SANDY CLAY

RED-BROWN CHERT WITH SOME RED GREENSTONE. FINE-GRAINED, HIGHLY FRACTURED

BLACK TO DARK GRAY LAMINATIONS OF SILTSTONE AND GRAYWACKE. FRESH TO MODERATELY WEATHERED, MODERATELY STRONG. MODERATE TO HIGH SUSCEPTIBILITY TO SLAKING. MOSTLY BRECCIATED WITH CLAY OR SLICKENSIDED SHALE MATRIX

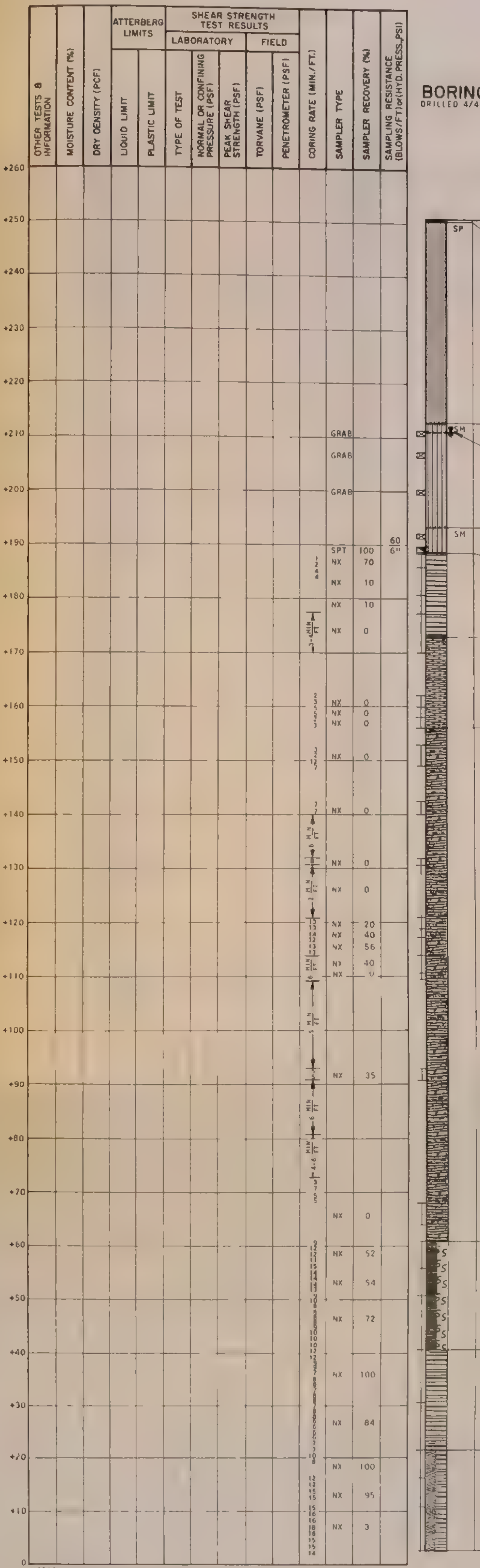
NOTES:
1. SAMPLING RESISTANCE:
   SPT DRIVEN BY 140 POUND FALLING 30"
2. ELEVATIONS REFER TO S.F. DATUM AND BASED ON OFFICIAL CITY GRADE
3. REFER TO FOLLOWING GEOLOGIC LOGS FOR A MORE DETAILED DESCRIPTION OF THE BEDROCK

**DAMES & MOORE**

PLATE A-IW

# BORING 23

DRILLED 4/4-20/78



ELEVATION +251'

2' ASPHALTIC PAVEMENT

BROWN TO YELLOW-BROWN FINE SAND (DUNE SAND)

BROWN AND RED-BROWN SILTY FINE SAND (COLMA FORMATION)

(WATER LEVEL 8/22/78)

BROWN AND GRAY SILTY FINE SAND WITH SOME FINE CHERT FRAGMENTS (COLLUVIUM)
(GRADING WITH WEATHERED SANDSTONE FRAGMENTS)

GRAY-BROWN FINE TO MEDIUM GRAINED GRAYWACKE MODERATELY WEATHERED MODERATELY STRONG HIGHLY HIGHLY FRACTURED. IRON STAINED JOINTS FILLED WITH A SANDY CLAY

RED-BROWN CHERT WITH SOME RED GREENSTONE. FINE-GRAINED HIGHLY FRACTURED

GREENSTONE WITH SOME CHERT HIGHLY FRACTURED. DARK GREEN AND DARK RED-BROWN

(SLIGHTLY WEATHERED, STRONG)

MELANGE-BLACK SLICKENSIDED SHALE AND GRAY CLAY MATRIX, SLIGHTLY WEATHERED, WEAK. NUMEROUS INCLUSIONS OF GREENSTONE, GRAYWACKE AND SERPENTINE ARE BRECCIATED TO SAND AND GRAVEL-SIZED FRAGMENTS. HIGH SUSCEPTIBILITY TO SLAKING

GRAY GRAYWACKE, THICK BEDDED FRESH TO SLIGHTLY WEATHERED AND STRONG. MINOR CALCITE VEINLETS.

(SHEAR ZONE)

(SHEAR ZONE)

(SHEAR ZONE, SLICKENSIDED SHALE LAMINATIONS)

BLACK TO DARK GRAY LAMINATIONS OF SILTSTONE AND GRAYWACKE. FRESH TO MODERATELY WEATHERED, MODERATELY STRONG. MODERATE TO HIGH SUSCEPTIBILITY TO SLAKING. MOSTLY BRECCIATED WITH CLAY OR SLICKENSIDED SHALE MATRIX

NOTES

1. SAMPLING RESISTANCE:
SPT DRIVEN BY 140 POUND FALLING 30"
2. ELEVATIONS REFER TO S.F. DATUM AND BASED ON OFFICIAL CITY GRADE
3. REFER TO FOLLOWING GEOLOGIC LOGS FOR A MORE DETAILED DESCRIPTION OF THE BEDROCK

**DAMES & MOORE**

PLATE A-1W

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)

BORING NO. 23

PROJECT: RICHMOND TRANSPORT SEWER

DRILLING METHOD: ROTARY WASH (NQ-CORING) WITH REVERT SLURRY

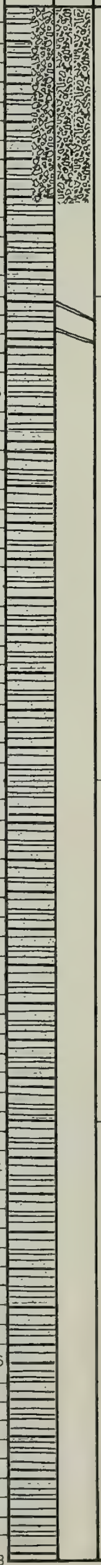
ANGLE FROM HORIZONTAL 90°

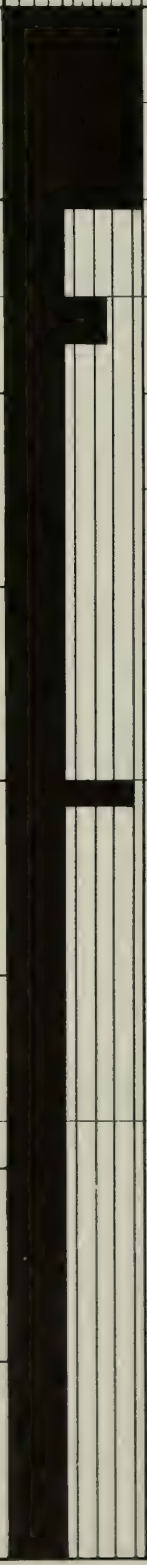
LOCATION LINCOLN PARK NEAR PRO-SHOP

ELEV. 251

PAGE 1 OF 10

| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| GRAYWACKE | LIGHT TO MEDIUM ORANGE-BROWN FINE SAND SIZE MATERIAL WITH A HIGH PROPORTION OF CLAYEY SAND MATRIX, THICK BEDDED TO MASSIVE | 188 | 62<br>64 | 70 | EXTREMELY FRACTURED<br>MATRIX HIGH SUSCEPTIBILITY TO SLAKING | 1<br>2<br>4 | RUN #1 |
| | MEDIUM BROWN GRAY FINE SAND SIZE MATERIAL, MEDIUM BEDDED | 186<br>184<br>182 | 66<br>68 | 10 | OXIDE COATING ON FRACTURE SURFACES | -<br>4<br>- | RUN #2<br>CASING SET TO 70' SAND CAVING INTO BORING |
| | SAME | 180<br>178 | 70<br>72 | 10 | SAME | - | RUN #3 |
| | | 176<br>174 | 74<br>76<br>78 | 0 | | 20 MIN. 7.5' | RUN #4 |





WEATHERING (SEE BELOW): FR, SW, MW, HW, XW

STRENGTH (SEE BELOW): VW, W, MS, S, VS

## LOG OF BORING

DAMES & MOORE

PLATE A-1W/1

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 23
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NQ-CORING) WITH REVERT SLURRY
LOCATION LINCOLN PARK NEAR PRO-SHOP
ELEV. 251
PAGE 2 OF 10

| ROCK TYPE | WEATHERING (SEE BELOW) | STRENGTH (SEE BELOW) | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | GRAPHIC LOG | FRACTURE ORIENTATION | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | RQD 75 50 25 | FRACTURES PER FOOT 1 4 16 64 | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CHERT WITH SOME GREENSTONE | | | RED BROWN VERY FINE GRAINED CHERT AND RED FINE GRAINED GREENSTONE | 172 | 78<br>80 | | 0 | | | | | 20 MIN. 7.5' | RUN #4 (CONT.)<br>NO CORE RECOVERY<br>IDENTIFICATION FROM CUTTINGS |
| | | | CUTTINGS SHOW CHERT WITH SOME GREENSTONE | 170<br>168<br>166<br>164 | 82<br>84<br>86<br>88 | | | | | | | 12<br>8 | 8' TRICONE DRILLING |
| | | | | 162 | 90 | | | 0 | | | | 1.5<br>1.5 | RUN #5 |
| | | | SAME | 160 | 92 | | | 0 | | | | 5<br>5 | RUN #6<br>88' CASING. MIXED REVERT, SLOW CORING<br>SLOW ROTATION<br>CARBIDE BIT |
| | | | | 158 | 94 | | | 0 | | | | 2 | RUN #7<br>SPEEDED UP ROTATION |

FR — SW — MW — HW — XW
VW — W — MS — S — VS

# LOG OF BORING

DAMES & MOORE

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)

BORING NO. 23

PROJECT: RICHMOND TRANSPORT SEWER

DRILLING METHOD: ROTARY WASH (NQ-CORING) WITH REVERT SLURRY

ANGLE FROM HORIZONTAL 90°

LOCATION LINCOLN PARK NEAR PRO-SHOP

ELEV. 251

PAGE 3 OF 10

| ROCK TYPE | WEATHERING (SEE BELOW) | STRENGTH (SEE BELOW) | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | GRAPHIC LOG | FRACTURE ORIENTATION | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | RQD 75 50 25 | FRACTURES PER FOOT 1 4 16 64 | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CHERT WITH SOME GREENSTONE | | | | | 94 | | | 0 | | | | 3 | RUN #7 (CONT.) BROWN WASH WATER |
| GREENSTONE WITH SOME CHERT | | | CUTTINGS SHOW GREENSTONE WITH SOME CHERT<br>DARK OLIVE GREEN ANGULAR CHIPS WITH FEW DARK RED BROWN FRAGMENTS. FEW WHITE QUARTZ CHIPS IN WASH MATERIAL | 156 | | | | | SOME WEATHERED SURFACES | | | | TRICONE DRILL BIT USED TO THE DEPTH OF 98' |
| | | | | | 96 | | | | | | | | |
| | | | | 154 | | | | | | | | | |
| | | | | | 98 | | | 0 | | | | 2.5 | RUN #8 IDENTIFICATION FROM CUTTINGS |
| | | | | 152 | | | | | | | | 2 | |
| | | | | | 100 | | | | | | | 12 | |
| | | | | 150 | | | | | | | | 7 | |
| | | | | | 102 | | | | | | | 2 | TRICONE DRILL BIT USED TO THE DEPTH OF 109' (ELEV. 142') |
| | | | | 148 | | | | | | | | 2 | |
| | | | | | 104 | | | | | | | 2 | |
| | | | | 146 | | | | | | | | 4 | |
| | | | | | 106 | | | | | | | 4 | |
| | | | | 144 | | | | | | | | 6 | |
| | | | | | 108 | | | | | | | 8 | OVERNIGHT ABOUT 5' OF SLOUGH IN HOLE |
| | | | SAME | 142 | | | | 0 | | | | 7 | RUN #9 |
| | | | | | 110 | | | | | | | | |

FR SW MW HW XW

VW W MS S VS

LOG OF BORING

**DAMES & MOORE**

PLATE A-1W/3

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 23
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NQ-CORING) WITH REVERT SLURRY
LOCATION LINCOLN PARK NEAR PRO-SHOP
ELEV. 251
PAGE 4 OF 10

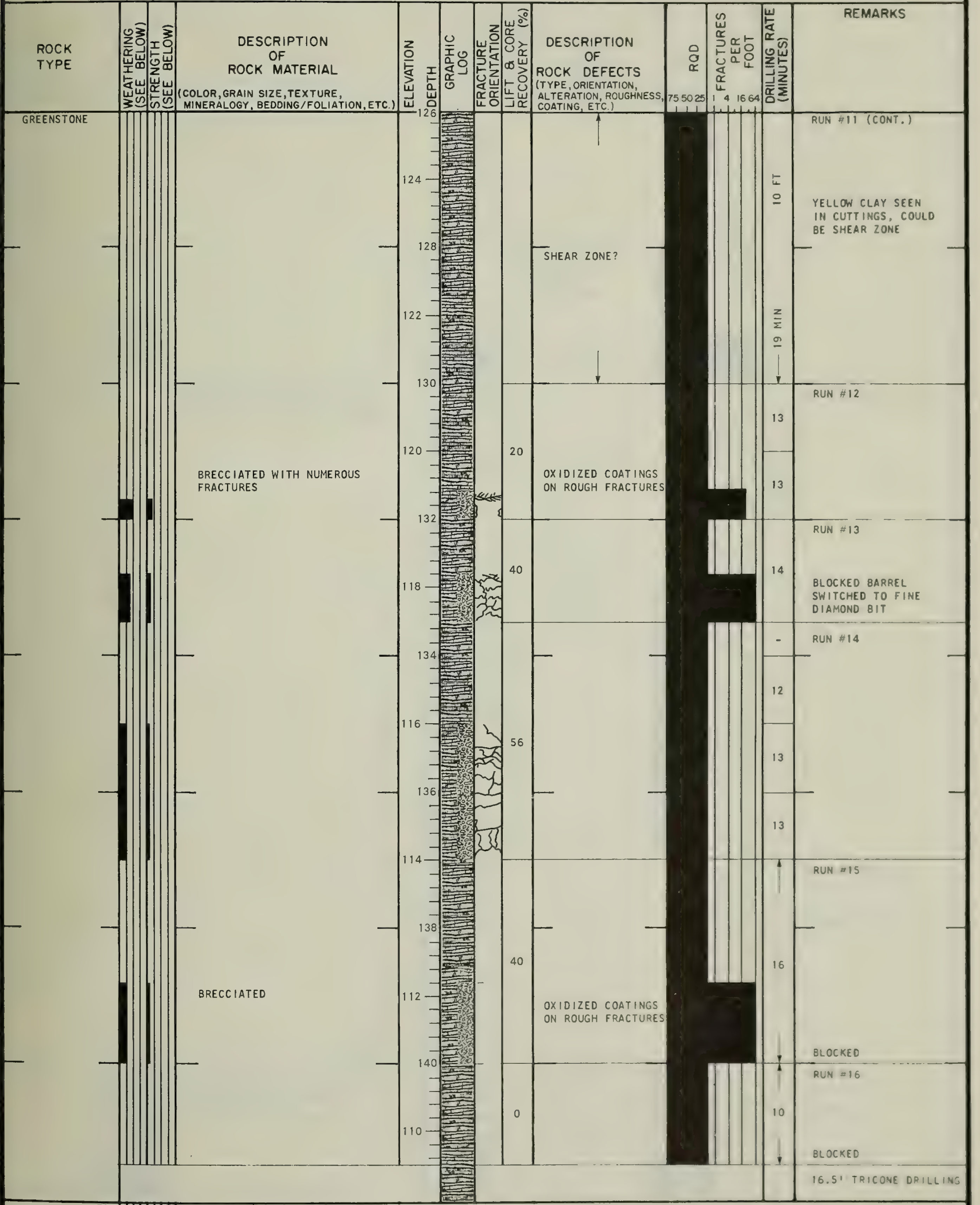
| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| GREENSTONE | GREENISH BROWN TO REDDISH BROWN | 141–140 | 110–111 | 0 |  | 7 | RUN #9 (CONT.) |
|  | CUTTINGS SHOW GREEN GREENSTONE THEREFORE GRADING LESS WEATHERED | 140–132 | 111–119 |  |  | 6<br>6<br>6<br>6<br>6<br>6<br>7<br>7 | TRICONE DRILL BIT USED TO THE DEPTH OF 119' |
|  | GREENISH BROWN WITH DARK YELLOW BROWN FINES IN WASH | 132–131 | 119–120 | 0 | SHEAR ZONE ? | 8 | RUN #10<br>IDENTIFICATION FROM CUTTINGS |
|  | CUTTINGS SHOW GREEN GREENSTONE WITH QUARTZ AND CHERT VEINLETS | 131–125 | 120–126 | 0 | SOME WEATHERED FRACTURE SURFACES | 19 MIN./10 FT | RUN #11 |

WEATHERING (SEE BELOW): FR, SW, MW, HW, XW
STRENGTH (SEE BELOW): VW, W, MS, S, VS

# LOG OF BORING

DAMES & MOORE

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 23
PROJECT: RICHMOND TRANSPORT SEWER
DRILLING METHOD: ROTARY WASH (NQ-CORING) WITH REVERT SLURRY
ANGLE FROM HORIZONTAL 90°
LOCATION LINCOLN PARK NEAR PRO-SHOP
ELEV. 251
PAGE 5 OF 10



| Depth | Rock type | Description of rock material | Lift & core recovery (%) | Description of rock defects | Drilling rate (minutes) | Remarks |
|---|---|---|---|---|---|---|
| 126–130 | GREENSTONE | | | SHEAR ZONE? | 10 FT — 19 MIN | RUN #11 (CONT.)<br>YELLOW CLAY SEEN IN CUTTINGS, COULD BE SHEAR ZONE |
| 130–132 | | BRECCIATED WITH NUMEROUS FRACTURES | 20 | OXIDIZED COATINGS ON ROUGH FRACTURES | 13<br>13 | RUN #12 |
| 132–133.5 | | | 40 | | 14 | RUN #13<br>BLOCKED BARREL SWITCHED TO FINE DIAMOND BIT |
| 133.5–137 | | | 56 | | -<br>12<br>13<br>13 | RUN #14 |
| 137–140 | | BRECCIATED | 40 | OXIDIZED COATINGS ON ROUGH FRACTURES | 16 | RUN #15<br>BLOCKED |
| 140–142 | | | 0 | | 10 | RUN #16<br>BLOCKED |
| | | | | | | 16.5' TRICONE DRILLING |

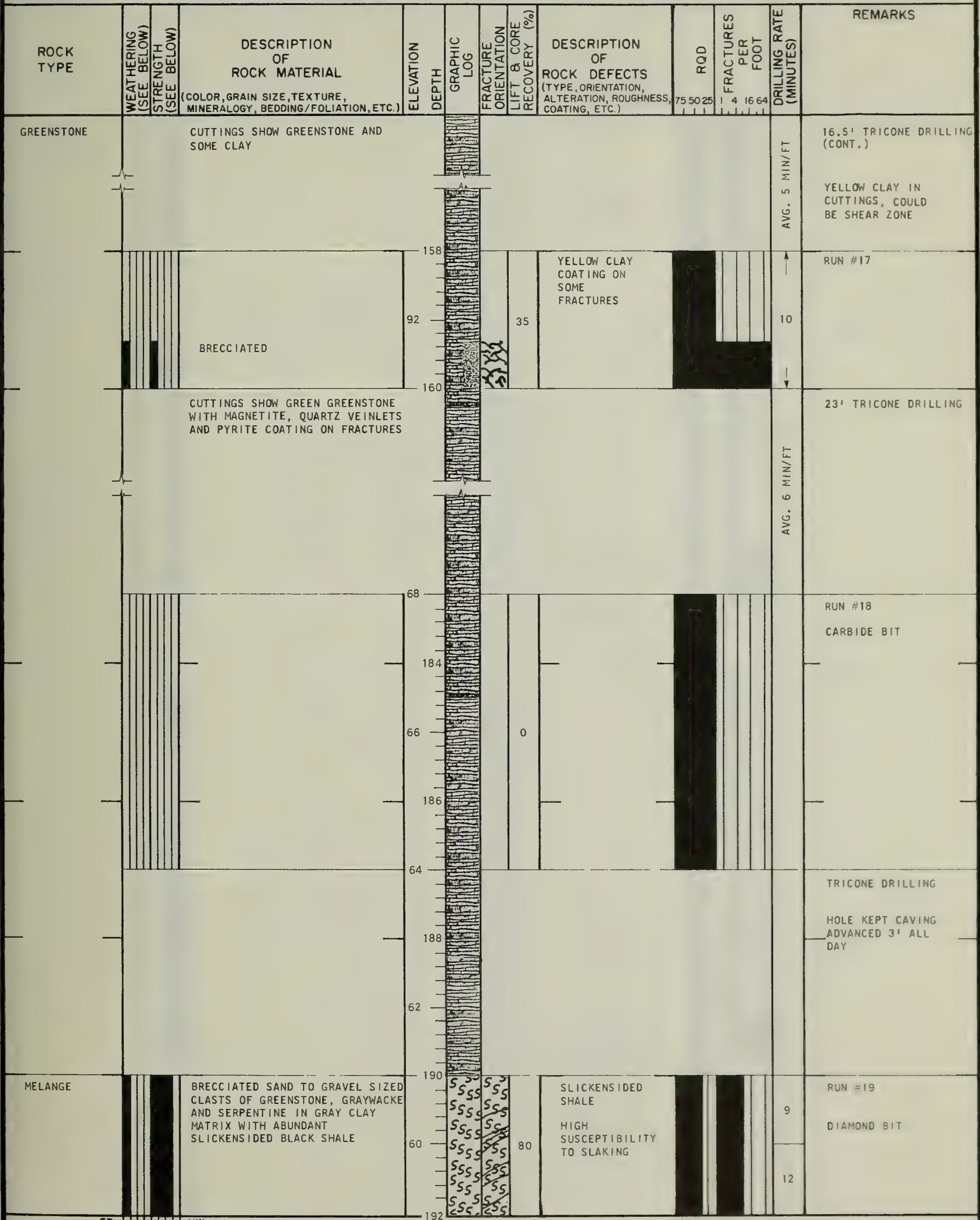
FR SW MW HW XW
VW W MS S VS

LOG OF BORING

**DAMES & MOORE**

PLATE A-1W/5

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 23
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NQ-CORING) WITH REVERT SLURRY
LOCATION LINCOLN PARK NEAR PRO-SHOP
ELEV. 251
PAGE 6 OF 10



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|
| GREENSTONE | CUTTINGS SHOW GREENSTONE AND SOME CLAY | | | AVG. 5 MIN/FT | 16.5' TRICONE DRILLING (CONT.)<br>YELLOW CLAY IN CUTTINGS, COULD BE SHEAR ZONE |
| | BRECCIATED | 35 | YELLOW CLAY COATING ON SOME FRACTURES | 10 | RUN #17 |
| | CUTTINGS SHOW GREEN GREENSTONE WITH MAGNETITE, QUARTZ VEINLETS AND PYRITE COATING ON FRACTURES | | | AVG. 6 MIN/FT | 23' TRICONE DRILLING |
| | | 0 | | | RUN #18<br>CARBIDE BIT |
| | | | | | TRICONE DRILLING<br>HOLE KEPT CAVING ADVANCED 3' ALL DAY |
| MELANGE | BRECCIATED SAND TO GRAVEL SIZED CLASTS OF GREENSTONE, GRAYWACKE AND SERPENTINE IN GRAY CLAY MATRIX WITH ABUNDANT SLICKENSIDED BLACK SHALE | 80 | SLICKENSIDED SHALE<br>HIGH SUSCEPTIBILITY TO SLAKING | 9<br>12 | RUN #19<br>DIAMOND BIT |

FR
SW
MW
HW
XW

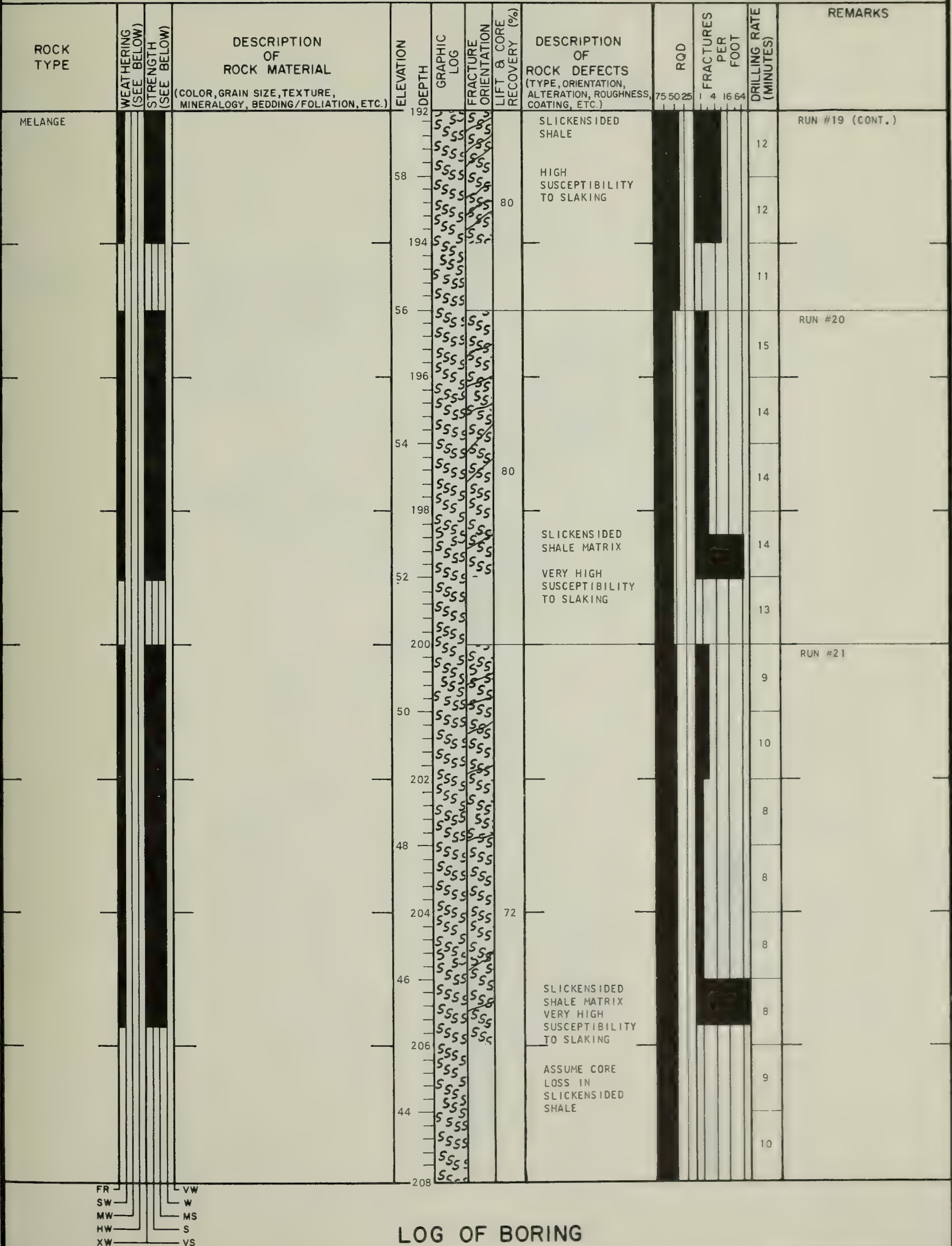
VW
W
MS
S
VS

# LOG OF BORING

**DAMES & MOORE**

PLATE A-IW/6

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 23
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NQ-CORING) WITH REVERT SLURRY
LOCATION LINCOLN PARK NEAR PRO-SHOP
ELEV. 251
PAGE 7 OF 10



SLICKENSIDED SHALE

HIGH SUSCEPTIBILITY TO SLAKING

SLICKENSIDED SHALE MATRIX

VERY HIGH SUSCEPTIBILITY TO SLAKING

SLICKENSIDED SHALE MATRIX
VERY HIGH SUSCEPTIBILITY TO SLAKING

ASSUME CORE LOSS IN SLICKENSIDED SHALE

RUN #19 (CONT.)

RUN #20

RUN #21

# LOG OF BORING

DAMES & MOORE

PLATE A-1W/7

CLIENT CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)

BORING NO. 23

PROJECT RICHMOND TRANSPORT SEWER

ANGLE FROM HORIZONTAL 90°

DRILLING METHOD: ROTARY WASH (NQ-CORING) WITH REVERT SLURRY

LOCATION LINCOLN PARK NEAR PRO-SHOP

ELEV 251

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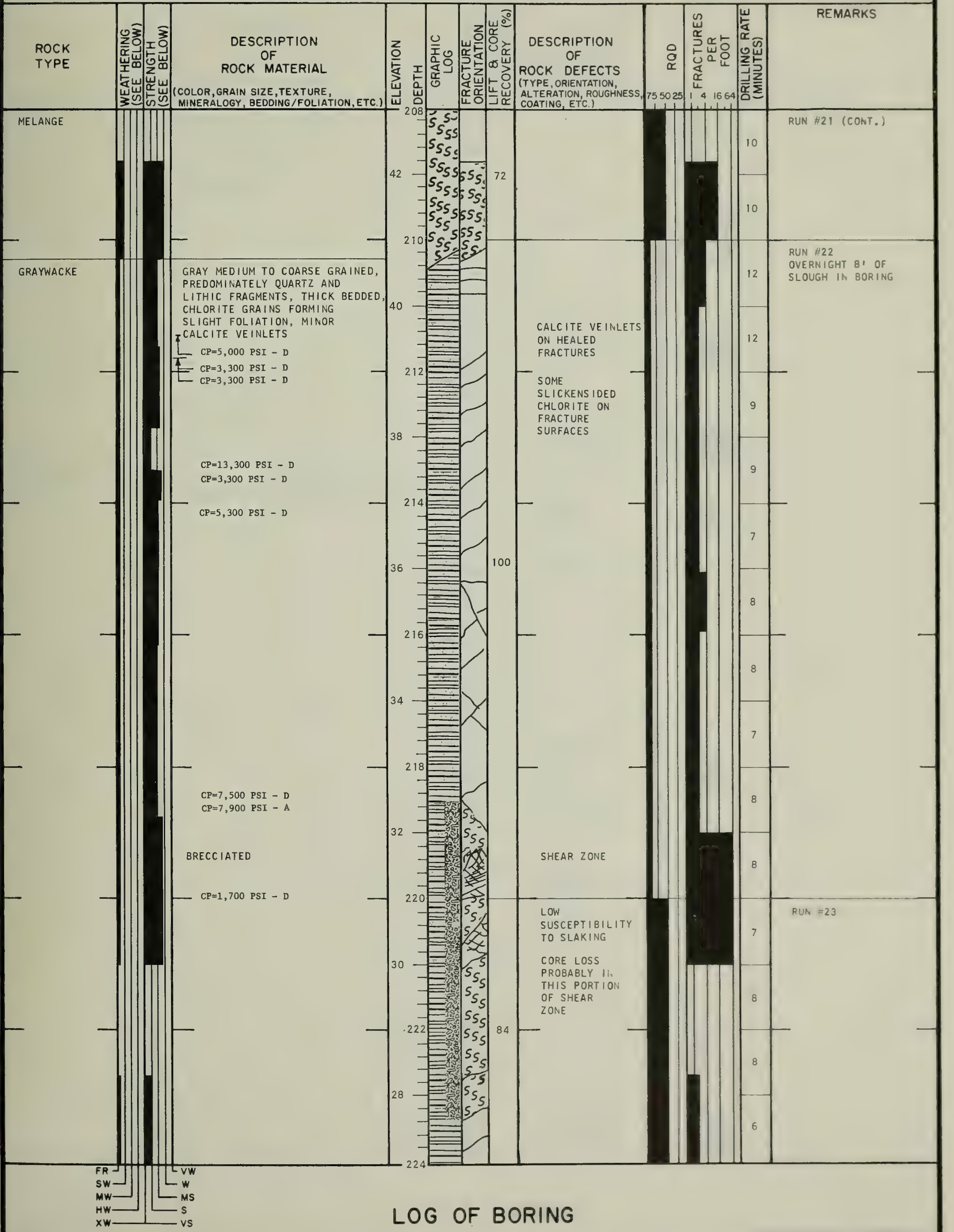


MELANGE

RUN #21 (CONT.)

GRAYWACKE

GRAY MEDIUM TO COARSE GRAINED, PREDOMINATELY QUARTZ AND LITHIC FRAGMENTS, THICK BEDDED, CHLORITE GRAINS FORMING SLIGHT FOLIATION, MINOR CALCITE VEINLETS

CP=5,000 PSI - D
CP=3,300 PSI - D
CP=3,300 PSI - D

RUN #22
OVERNIGHT 8' OF SLOUGH IN BORING

CALCITE VEINLETS ON HEALED FRACTURES

SOME SLICKENSIDED CHLORITE ON FRACTURE SURFACES

CP=13,300 PSI - D
CP=3,300 PSI - D

CP=5,300 PSI - D

CP=7,500 PSI - D
CP=7,900 PSI - A

BRECCIATED

SHEAR ZONE

CP=1,700 PSI - D

LOW SUSCEPTIBILITY TO SLAKING

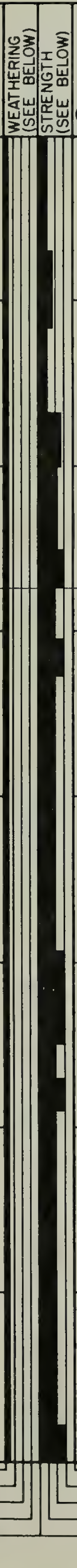
CORE LOSS PROBABLY IN THIS PORTION OF SHEAR ZONE

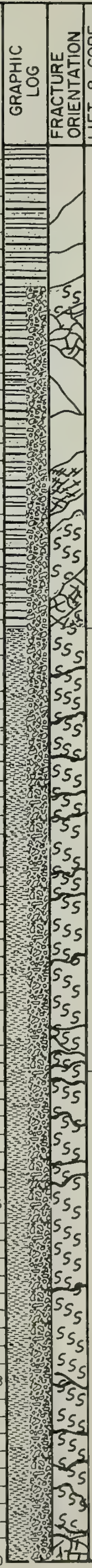
RUN #23

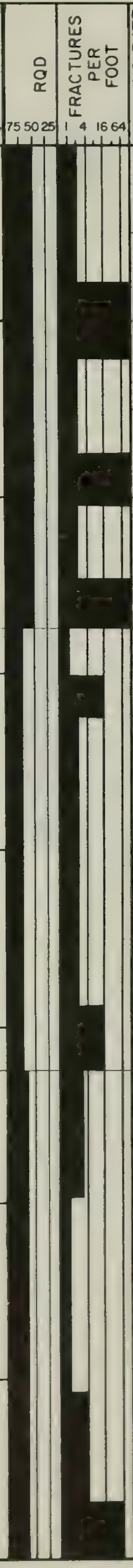
# LOG OF BORING

**DAMES & MOORE**

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 23
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NQ-CORING) WITH REVERT SLURRY
LOCATION LINCOLN PARK NEAR PRO-SHOP
ELEV. 251
PAGE 9 OF 10







| ELEVATION | DEPTH | ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| | 224 | GRAYWACKE | | | | 6 | RUN #23 (CONT.) |
| 26 | | | BRECCIATED | | | 6 | |
| | | | | | SHEAR ZONE | | |
| | 226 | | | | | 6 | |
| 24 | | | | 84 | SLICKENSIDED SHALE LAMINATIONS | 7 | |
| | 228 | | | | SHEAR ZONE | | |
| | | | CP=4,200 PSI - D | | CLAY MATRIX TO SHEAR ZONE HIGH SUSCEPTIBILITY TO SLAKING | 7 | |
| 22 | | | BRECCIATED | | | 4 | |
| | | SILTSTONE | BLACK TO DARK GRAY BRECCIATED LAMINATIONS OF SILTSTONE AND VERY FINE GRAINED GRAYWACKE | | SHEAR ZONE | | RUN #24 |
| | 230 | | | | HIGHLY BRECCIATED | 10 | |
| 20 | | | | | SLICKENSIDED SHALE | 8 | |
| | 232 | | | 100 | | | |
| 18 | | | | | | - | |
| | 234 | | | | BRECCIATED WITH CLAY MATRIX | | |
| 16 | | | | | SLICKENSIDED SHALE MATRIX | - | RUN #25 |
| | | | | | | - | |
| | 236 | | | | MODERATE SUSCEPTIBILITY TO SLAKING, SOME CLAY MATRIX | 12 | |
| 14 | | | | 100 | | 12 | |
| | 238 | | | | | 15 | |
| 12 | | | | | HIGH SUSCEPTIBILITY TO SLAKING | 15 | |
| | 240 | | | | | | |

LOG OF BORING

DAMES & MOORE

PLATE A-1W/9

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)

BORING NO. 23

PROJECT: RICHMOND TRANSPORT SEWER

ANGLE FROM HORIZONTAL 90°

DRILLING METHOD: ROTARY WASH (NQ-CORING) WITH REVERT SLURRY

LOCATION LINCOLN PARK NEAR PRO-SHOP

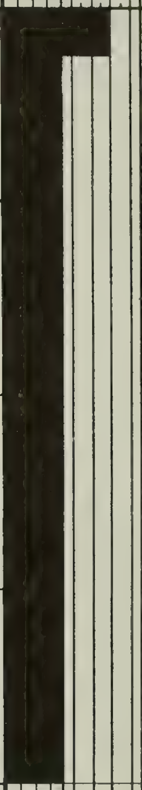
ELEV. 251

PAGE 10 OF 10

| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | FRACTURE ORIENTATION | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|---|
| SILTSTONE | 6" CORE CONSISTS OF PEBBLE SIZED CLASTS OF SILTSTONE AND BRECCIATED GRAYWACKE | | 240 | S<br>SSS | | | 15 | RUN #26 |
| | | 10 | | | | | 16 | |
| | | | 242 | | | | 16 | |
| | | 8 | | | | | 18 | |
| | | | 244 | | 5 | | 16 | |
| | | 6 | | | | | 15 | |
| | | | 246 | | | | 15 | |
| | | 4 | | | | | 14 | |
| | | | 248 | | | | | TERMINATED BORING AT ELEVATION 3' DEPTH AT 248' |

WEATHERING (SEE BELOW) STRENGTH (SEE BELOW) GRAPHIC LOG

RQD 75 50 25 FRACTURES PER FOOT 1 4 16 64



FR SW MW HW XW

VW W MS S VS

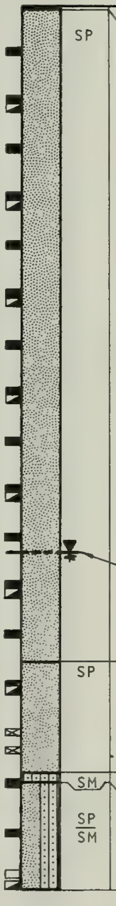
## LOG OF BORING

**DAMES & MOORE**

PLATE A-1W/10

## BORING 24
DRILLED 4/4-5/78

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS |  | SHEAR STRENGTH TEST RESULTS |  |  |  |  | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT) or (HYD. PRESS., PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | LABORATORY |  |  | FIELD |  |  |  |  |  |
|  |  |  |  | LIQUID LIMIT | PLASTIC LIMIT | TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | TORVANE (PSF) | PENETROMETER (PSF) |  |  |  |  |
| +90 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| +80 |  | 6 | 104 |  |  |  |  |  |  |  |  | U | 83 | 15 |
|  |  | 4 | 105 |  |  |  |  |  |  |  |  | U<br>SPT | 83<br>100 | 19<br>19 |
| +70 |  | 5 | 108 |  |  |  |  |  |  |  |  | U | 89 | 74 |
|  |  | 5 | 104 |  |  |  |  |  |  |  |  | U<br>SPT | 89<br>100 | 22<br>17 |
| +60 | SA (1%) | 4 | 103 |  |  |  |  |  |  |  |  | U | 89 | 34 |
|  |  | 5 | 109 |  |  |  |  |  |  |  |  | U<br>SPT | 89<br>100 | 44<br>40 |
| +50 |  | 5 | 107 |  |  |  |  |  |  |  |  | U | 89 | 24 |
|  | SA (5%) | 7 | 104 |  |  |  |  |  |  |  |  | U<br>SPT | 89<br>100 | 16<br>34 |
| +40 |  | 7 | 102 |  |  | DS/CD | 5500 | 3260 |  |  |  | U | 89 | 28 |
|  |  | 13 | 105 |  |  |  |  |  |  |  |  | U<br>SPT | 28<br>100 | 157<br>124 |
| +30 | PERM<br>SA (2%) | 17 | 115 |  |  |  |  |  |  |  |  | U | 89 | 100/3" |
|  |  | 20 | 110 |  |  | DS/CD | 6300 | 4740 |  |  |  | U<br>SPT | 83<br>56 | 120/6"<br>32 |
| +20 | PERM<br>SA (7%) | 18 | 117 |  |  | DS/CD | 6500 | 6040 |  |  |  | U | 67 | 151 |
|  | SA (5%) | 19 | 108 |  |  |  |  |  |  |  |  | TW<br>SPT | 100<br>56 | 130/2.5"<br>102 |
| +10 | SA (11%) |  |  |  |  |  |  |  |  |  |  | U | 63 | 100/1.5" |
|  | SA (4%) | 21 | 120 |  |  |  |  |  |  |  |  | TW | 58 | 120/6" |
|  | PERM<br>SA (34%) | 16 | 118 |  |  |  |  |  |  |  |  | TW | 71 | 100/5" |
| 0 |  | 25 | 102 |  |  |  |  |  |  |  |  | TW | 83 | 106/6" |
|  |  |  |  |  |  |  |  |  |  |  |  | TW<br>SPT | 0<br>100 | 105/2"<br>110 |
| -10 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |



ELEVATION +85'

3" ASPHALT CONCRETE

SP BROWN FINE SAND (DUNE SAND) (LOOSE TO MEDIUM DENSE) (SLIGHTLY MOIST)

(GRADING MEDIUM DENSE)

(GRADING DARK BROWN, SLIGHTLY SILTY)

(GRADING BROWN, LESS SILTY)

(GRADING VERY DENSE)

(LENSE OF GRAY FINE SANDY SILT)

(WATER LEVEL 8/22/78)

(TRACE SILT)

SP YELLOWISH-BROWN SLIGHTLY SILTY MEDIUM FINE SAND WITH OCCASIONAL IRON OXIDE STAINING (VERY DENSE) (COLMA FORMATION)

(SILT GRADING TO TRACE)

SM YELLOWISH-BROWN SILTY MEDIUM FINE SAND (VERY DENSE)

SP/SM BROWN SLIGHTLY SILTY VERY FINE SAND (VERY DENSE)

NOTES:

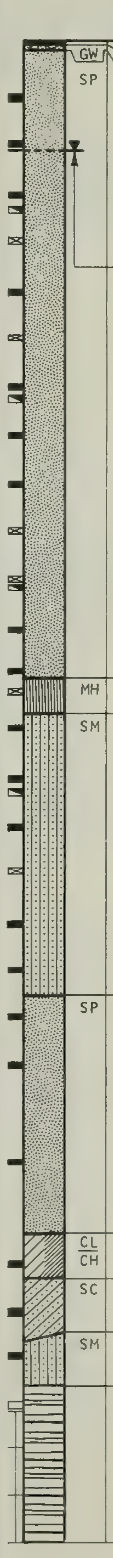
1. SAMPLING RESISTANCE:
   U, TW AND SPT DRIVEN WITH A 140 POUND HAMMER FALLING 30".
2. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED ON OFFICIAL CITY GRADE.

# LOG OF BORING

# BORING 25

DRILLED 7/10-12/78

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS |  | SHEAR STRENGTH TEST RESULTS |  |  |  |  | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD.PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | LABORATORY |  |  | FIELD |  |  |  |  |  |
|  |  |  |  | LIQUID LIMIT | PLASTIC LIMIT | TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | TORVANE (PSF) | PENETROMETER (PSF) |  |  |  |  |
| +100 |  | 4 | 109 |  |  |  |  |  |  |  |  | U-1 | 100 | 28 |
| +90 |  | 11 | 112 |  |  |  |  |  |  |  |  | U-1 | 50 | 52 |
|  |  | 13 | 113 |  |  |  |  |  |  |  |  | U-1<br>SPT | 100 | 96<br>53/3" |
| +80 |  | 14 | 116 |  |  |  |  |  |  |  |  | U-1 | 56 | 89 |
|  |  | 14 | 112 |  |  |  |  |  |  |  |  | U-1 | 100 | 91 |
| +70 |  |  |  |  |  |  |  |  |  |  |  | U-1 | 17 | 53/6" |
|  | SA (1%) | 15 | 110 |  |  |  |  |  |  |  |  | U-1<br>SPT | 88<br>73 | 95/11"<br>50/5" |
| +60 |  | 18 | 109 |  |  | DS/CU | 5000 | 3120 |  |  |  | U-1 |  | 96/11" |
|  | PERM.<br>SA (1%) |  |  |  |  |  |  |  |  |  |  | U-1 |  | 92/11" |
| +50 | SA (2%) | 20 |  |  |  |  |  |  |  |  |  | U-1 |  | 53/6" |
|  | SA (1%) | 23 |  |  |  |  |  |  |  |  |  | U-1<br>SPT |  | 50/4"<br>55/6" |
| +40 | SA (1%) | 23 |  |  |  |  |  |  |  |  |  | U-1 | 50 | 64/6" |
|  | SA (4%) | 22 | 109 |  |  | DS/CU | 7500 | 5280 |  |  |  | U-1<br>GRAB | 100 | 70/6" |
| +30 | SA (17%) | 19 | 111 |  |  | DS/CU | 7700 | 5160 |  |  |  | U-1 | 100 | 17 |
|  | PERM.<br>SA (14%) |  |  |  |  |  |  |  |  |  |  | U-1<br>SPT | 100<br>89 | 75<br>48 |
| +20 | SA (10%) | 19 | 111 |  |  | DS/CU | 8200 | 4380 |  |  |  | U-1 | 100 | 27 |
|  | SA (10%) | 19 | 110 |  |  |  |  |  |  |  |  | U-1 | 80 | 50/4" |
| +10 | PERM.<br>SA (27%) |  |  |  |  |  |  |  |  |  |  | U-1 | 91 | 82/11½" |
|  |  | 25 | 103 |  |  |  |  |  |  |  |  | U-1 | 75 | 50/6" |
| 0 |  | 22 | 104 |  |  |  |  |  |  |  |  | U-1 | 73 | 50/5" |
|  |  | 24 | 102 |  |  |  |  |  |  |  |  | U-1 | 73 | 50/5" |
| -10 |  | 27 | 97 |  |  |  |  |  |  |  |  | U-1 | 82 | 50/5" |
| -20 |  | 19 | 109 | 21 | 47 |  |  |  |  |  |  | U-1 | 100 | 77 |
| -30 |  | 17 | 113 |  |  |  |  |  |  |  |  | U-1 | 100 | 81 |
|  |  |  |  |  |  |  |  |  |  |  |  | U-1 | 45 | 60/5" |
| -40 |  |  |  |  |  |  |  |  |  |  |  | U-1 | 0 | 100/1" |
|  |  |  |  |  |  |  |  |  |  |  | 20<br>22<br>19<br>21<br>17<br>18<br>16<br>15<br>17<br>15<br>11<br>20<br>13 | NX | 100 |  |
|  |  |  |  |  |  |  |  |  |  |  |  | NX | 100 |  |
| -50 |  |  |  |  |  |  |  |  |  |  |  | NX | 100 |  |
| -60 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |



ELEVATION +99'

|  |  |
|---|---|
|  | ASPHALTIC CONCRETE |
| GW | GRAY-BROWN SLIGHTLY SILTY FINE SANDY GRAVEL (FILL) |
| SP | BROWN FINE SAND (DUNE SAND)<br>(GRADING MEDIUM DENSE @ 5½')<br>(GRADING TO DENSE)<br>(GRADING TO VERY DENSE)<br>(GRADING DARK GRAY AND BROWN)<br>(WATER LEVEL IN LOWER PIEZOMETER, BOTTOM AT +19', 11/15/78. SEAL AT 31'; PIEZOMETER MAY BE PLUGGED UP)<br>(BOTTOM OF UPPER PIEZOMETER @ 42', DRY)<br>(GRADING SILTY) |
| MH | BLACK SANDY CLAYEY SILT (COLMA FORMATION)<br>(GRADING ORANGE BROWN) |
| SM | BROWN SILTY FINE SAND (MEDIUM DENSE)<br>(GRADING TO VERY DENSE)<br>(TRACE OF GRAVEL)<br>(GRADING DARK RED-BROWN WITH SLIGHT IRON OXIDE CEMENTATION)<br>(SLIGHT IRON OXIDE CEMENTATION)<br>(SLIGHT CEMENTATION) |
| SP | BROWN FINE SAND WITH TRACE OF SILT (VERY DENSE) |
| CL/CH | GRAY AND BROWN SANDY CLAY (HARD) |
| SC | LIGHT GRAY AND BROWN CLAYEY FINE SAND WITH SOME SILT, IRON OXIDE STAINING (VERY DENSE) |
| SM | BROWN SILTY FINE SAND WITH SOME ROCK FRAGMENTS (VERY DENSE)(COLLUVIUM) |
|  | LIGHT GRAY BROWN GRAYWACKE (FRANCISCAN BEDROCK) FINE-GRAINED, MASSIVE, RQD = 0 TO 25. MODERATELY WEATHERED, STRONG. CLAY COATED FRACTURES.<br>(GRADING MODERATELY STRONG) |

NOTES:

1. SAMPLING RESISTANCE:
   SPT DRIVEN BY 140# HAMMER FALLING 30"
   U DRIVEN BY 265# SLIPJARS FALLING 18"
2. ELEVATION REFER TO S.F. DATUM AND ARE BASED ON OFFICIAL CITY GRADE
3. SEE THE FOLLOWING GEOLOGIC LOGS FOR A MORE DETAILED DESCRIPTION OF THE BEDROCK

# LOG OF BORING

**DAMES & MOORE**

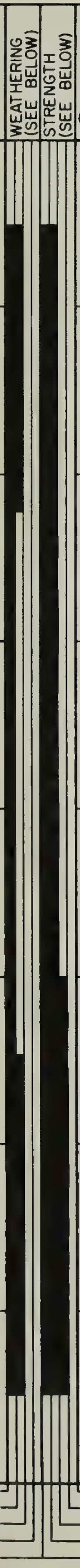
PLATE A-1Y

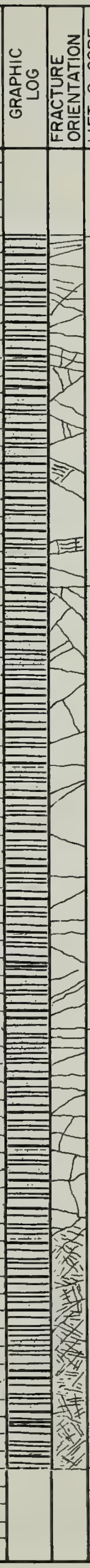
| | |
|---|---|
| CLIENT: | CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03) |
| BORING NO. | 25 |
| PROJECT: | RICHMOND TRANSPORT SEWER |
| ANGLE FROM HORIZONTAL | 90° |
| DRILLING METHOD: | ROTARY WASH (FAILING 750) |
| LOCATION | 26TH AVE. / EL CAMINO DEL MAR |
| ELEV. | 99 |
| PAGE | 1 OF 1 |

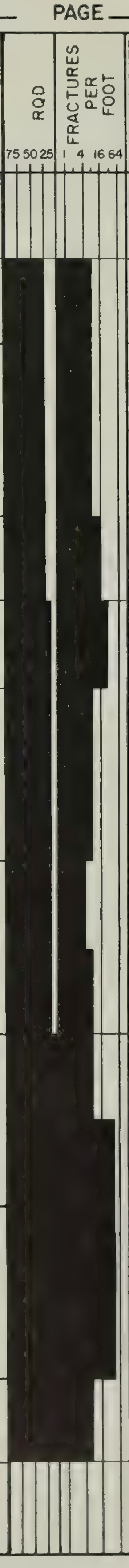
| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | REMARKS |
|---|---|---|---|---|---|---|
| GRAYWACKE | LIGHT GRAY BROWN FINE SAND SIZE MATERIAL. MASSIVE. | -42 | | | MODERATELY FRACTURED WITH SANDY SILT COATINGS | RUN #1<br>DP=0 PSI<br>DIAMOND BIT |
| | | | 142 | | | |
| | | -44 | | 100 | | |
| | CP=10700 PSI - D | | 144 | | | |
| | CP=3100 PSI - D | | | | | |
| | MEDIUM TO DARK BLUE GRAY FINE SAND SIZE MATERIAL. MASSIVE. | -46 | | | SLIGHT TO MODERATELY FRACTURED WITH A FEW CLAY FILLINGS | RUN #2<br>DP=0 PSI<br>DIAMOND BIT |
| | | | 146 | | | |
| | | -48 | | 100 | MOST FRACTURES ROUGH | |
| | CP=2200 PSI - D | | 148 | | | |
| | | -50 | | | | |
| | | | 150 | | | RUN #3<br>DP=0 PSI |
| | CP=1100 PSI - A | -52 | | | FEW CALCITE VEINLETS | |
| | | | 152 | 100 | CLAY FILLINGS | |
| | | -54 | | | | |
| | | | 154 | | | |
| | | -56 | | | | |

DRILLING RATE (MINUTES)

| DEPTH | DRILLING RATE (MINUTES) |
|---|---|
| 141–142 | 20 |
| 142–143 | 22 |
| 143–144 | 19 |
| 144–145 | 21 |
| 145–146 | 17 |
| 146–147 | 18 |
| 147–148 | 16 |
| 148–149 | 15 |
| 149–150 | 17 |
| 150–151 | 15 |
| 151–152 | 11 |
| 152–153 | 20 |
| 153–154 | 13 |
| 154–155 | 17 |







## LOG OF BORING

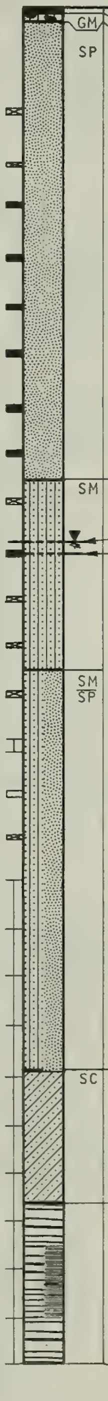
DAMES & MOORE

PLATE A-IY/1

## BORING 26

DRILLED 7/25-28/78

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS |  | SHEAR STRENGTH TEST RESULTS |  |  |  |  | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD.PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | LABORATORY |  |  | FIELD |  |  |  |  |  |
|  |  |  |  | LIQUID LIMIT | PLASTIC LIMIT | TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | TORVANE (PSF) | PENETROMETER (PSF) |  |  |  |  |
| +110 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| +100 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  | U-1 | 100 | 56 |
|  |  |  |  |  |  |  |  |  |  |  |  | U-1 | 33 | 84 |
| +90 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | 18 | 107 |  |  |  |  |  |  |  |  | U-1 | 89 | 72 |
|  |  | 20 | 103 |  |  |  |  |  |  |  |  | U-1 | 67 | 56 |
| +80 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | 21 | 105 |  |  |  |  |  |  |  |  | U-1 | 78 | 96 |
|  |  | 14 | 116 |  |  |  |  |  |  |  |  | U-1 | 67 | 50/6" |
| +70 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | PERM.<br>SA (5%) |  |  |  |  |  |  |  |  |  |  | U-1 | 78 | 74 |
|  | SA (1%) | 21 | 103 |  |  | DS/CU | 5700 | 3980 |  |  |  | U-1 | 100 | 90/11" |
| +60 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  | U-1 | 100 | 44 |
|  | SA (31%) | 14 | 119 |  |  | DS/CU | 7000 | 4720 |  |  |  | U-1 | 100 | 53 |
| +50 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | PERM.<br>SA (15%) |  |  |  |  |  |  |  |  |  |  | U-1 | 100 | 38 |
|  | SA (10%) | 19 | 111 |  |  |  |  |  |  |  |  | U-1 | 33 | 53/6" |
| +40 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | SA (7%) | 23 |  |  |  |  |  |  |  |  |  | U-1 | 50 | 63/6" |
|  |  |  |  |  |  |  |  |  |  |  | 1 | NX | 0 |  |
| +30 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  | U-1 | 0 | 47 |
|  | SA (4%) | 24 |  |  |  |  |  |  |  |  |  | U-1 | 67 | 50/6" |
| +20 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  | 2 MIN/FT. AVG. | NX | 90 |  |
| +10 | SA (4%) | 25 | 101 |  |  | DS/CU | 9000 | 6310 |  |  |  | NX | 40 |  |
|  |  |  |  |  |  |  |  |  |  |  |  | NX | 20 |  |
|  |  |  |  |  |  |  |  |  |  |  |  | NX | 90 |  |
| 0 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  | 5 | NX | 70 |  |
|  |  |  |  |  |  |  |  |  |  |  | 6<br>6<br>6<br>10<br>10<br>12<br>14<br>15<br>18<br>18<br>18<br>20<br>22<br>24<br>24<br>24<br>24<br>26<br>25<br>28 | NX | 100 |  |
| -10 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  | NX | 100 |  |
| -20 |  |  |  |  |  |  |  |  |  |  |  | NX | 80 |  |
|  |  |  |  |  |  |  |  |  |  |  |  | NX | 100 |  |
|  |  |  |  |  |  |  |  |  |  |  |  | NX | 100 |  |
| -30 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| -40 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |



ELEVATION +108'

ASPHALTIC CONCRETE

LIGHT GRAY BROWN SILTY SANDY GRAVEL (FILL)

DARK GRAY-BROWN FINE SAND (DUNE SAND)

(GRADING DENSE)

(GRADING VERY DENSE)

(UPPER PIEZOMETER, BASE AT +65', DRY)

(GRADING DARK BROWN)

BROWN SILTY FINE SAND (COLMA FORMATION)(DENSE
(GRADING REDDISH BROWN, IRON OXIDE MOTTLING)

(WATER LEVEL 11/15/78) LOWER PIEZOMETER BASE
(WATER LEVEL 8/2/78) AT -12', SEAL AT +53')

(GRADING LESS SILTY, PARTIALLY CEMENTED)

(GRADING LESS SILTY, PARTIALLY CEMENTED)

(GRADING DARK REDDISH BROWN, PARTIALLY CEMENTED)

(WEAK IRON OXIDE CEMENTATION IS PERVASIVE ENOUGH TO ALLOW CORING)

(GRADING WITH ALTERNATING LENSES OF SILT, SLIGHT TO MODERATE CEMENTATION WITH IRON OXIDE)

LIGHT TO MEDIUM BROWN AND GRAY SILTY CLAYEY FINE SAND WITH ROCK FRAGMENTS (COLLUVIUM)

(GRADING FEWER ROCK FRAGMENTS)

(GRADING BLUE-GRAY, WITH SANDSTONE FRAGMENTS)

GRAY GRAYWACKE (FRANCISCAN BEDROCK) WITH FEW BLACK SHALE PARTINGS, HIGHLY WEATHERED, WEAK

(GRADING WITH BLACK SHALE INTERBEDS, HIGHLY WEATHERED, WEAK. RQD = 0, EXTREMELY FRACTURED)

(GRAY GRAYWACKE, MODERATELY WEATHERED, WEAK TO MODERATELY STRONG, MODERATELY FRACTURED RQD = 35

NOTES:

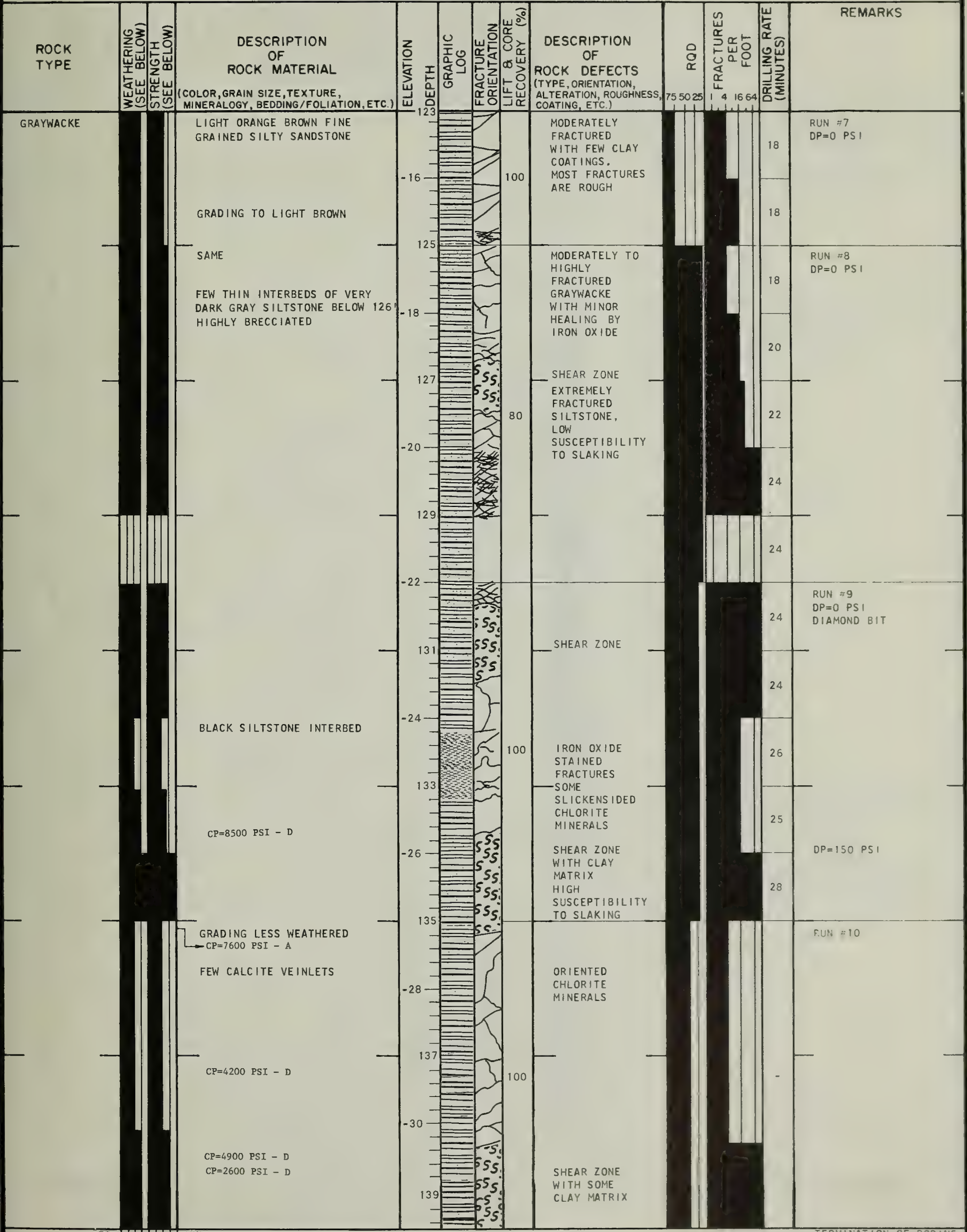
1. SAMPLING RESISTANCE:
   U DRIVEN WITH 265# SLIPJARS FALLING 18"
2. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED ON OFFICIAL CITY GRADE.
3. SEE FOLLOWING GEOLOGIC LOG FOR A MORE DETAILED DESCRIPTION OF THE BEDROCK.

# LOG OF BORING

**DAMES & MOORE**

PLATE A-17

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 26
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION EL CAMINO DEL MAR NEAR 27th. AVE.
ELEV. 108
PAGE 1 OF 1



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| GRAYWACKE | LIGHT ORANGE BROWN FINE GRAINED SILTY SANDSTONE | | 123 | | MODERATELY FRACTURED WITH FEW CLAY COATINGS. MOST FRACTURES ARE ROUGH | 18 | RUN #7<br>DP=0 PSI |
| | GRADING TO LIGHT BROWN | -16 | | 100 | | 18 | |
| | SAME<br>FEW THIN INTERBEDS OF VERY DARK GRAY SILTSTONE BELOW 126' | | 125 | | MODERATELY TO HIGHLY FRACTURED GRAYWACKE WITH MINOR HEALING BY IRON OXIDE | 18 | RUN #8<br>DP=0 PSI |
| | HIGHLY BRECCIATED | -18 | | | | 20 | |
| | | | 127 | 80 | SHEAR ZONE<br>EXTREMELY FRACTURED SILTSTONE, LOW SUSCEPTIBILITY TO SLAKING | 22 | |
| | | -20 | | | | 24 | |
| | | | 129 | | | 24 | |
| | | -22 | | | | 24 | RUN #9<br>DP=0 PSI<br>DIAMOND BIT |
| | | | 131 | | SHEAR ZONE | 24 | |
| | BLACK SILTSTONE INTERBED | -24 | | 100 | IRON OXIDE STAINED FRACTURES | 26 | |
| | CP=8500 PSI - D | | 133 | | SOME SLICKENSIDED CHLORITE MINERALS | 25 | |
| | | -26 | | | SHEAR ZONE WITH CLAY MATRIX HIGH SUSCEPTIBILITY TO SLAKING | 28 | DP=150 PSI |
| | GRADING LESS WEATHERED<br>CP=7600 PSI - A<br>FEW CALCITE VEINLETS | | 135 | | ORIENTED CHLORITE MINERALS | | RUN #10 |
| | | -28 | | | | | |
| | CP=4200 PSI - D | | 137 | 100 | | - | |
| | CP=4900 PSI - D<br>CP=2600 PSI - D | -30 | | | SHEAR ZONE WITH SOME CLAY MATRIX | | |
| | | | 139 | | | | |

FR
SW
MW
HW
XW

VW
W
MS
S
VS

LOG OF BORING

TERMINATION OF BORING AT ELEVATION -31.5 DEPTH IS 139.5

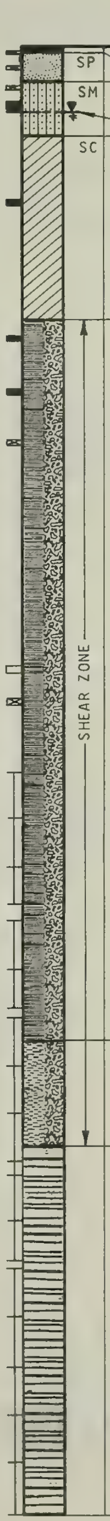
DAMES & MOORE

PLATE A-12/1

## BORING 27
DRILLED 7/13-25/78

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | SHEAR STRENGTH TEST RESULTS, LABORATORY: TYPE OF TEST | LABORATORY: NORMAL OR CONFINING PRESSURE (PSF) | LABORATORY: PEAK SHEAR STRENGTH (PSF) | FIELD: TORVANE (PSF) | FIELD: PENETROMETER (PSF) | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD.PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| +150 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | GRAB<br>GRAB<br>GRAB | | |
| | | 18 | 105 | | | | | | | | | U-1 | 89 | 20 |
| +140 | | | | | | | | | | | | | | |
| | | 23 | 104 | | | | | | | | | U-1 | 100 | 35 |
| +130 | | | | | | | | | | | | | | |
| +120 | | | | | | | | | | | | | | |
| | | 18 | 107 | 50 | 28 | TX/CU | 2150 | 1350 | | | | U-1 | 100 | 41 |
| | | 6 | 144 | | | | | | | | | U-1 | 100 | 71 |
| +110 | | | | | | | | | | | | | | |
| | | 13 | | 29 | 20 | | | | | | | U-1 | 50 | 66/6" |
| +100 | | | | | | | | | | | | | | |
| +90 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | U-1 | 0 | 100/6" |
| | | | | | | | | | | | | GRAB | | |
| +80 | | | | | | | | | | | | | | |
| | SWELL* | 11 | 128 | 28 | 17 | TX/CU | 8640 | 6050 | | | 10-12 MIN/FT. AVG | | | |
| | SWELL* | 10 | 131 | 28 | 17 | TX/CU | 8640 | 3490 | | | | NX | 100 | |
| +70 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | NX | 100 | |
| | | | | | | | | | | | | NX | 100 | |
| | SWELL* | 9 | 126 | 30 | 18 | TX/CU | 21600 | 4460 | | | | | | |
| +60 | | | | | | | | | | | | | | |
| | | | | | | | | | | | 15<br>15<br>14<br>20<br>16 | NX | 40 | |
| | | | | | | | | | | | 14<br>12<br>14<br>15 | NX | 100 | |
| | SWELL* | 13 | 124 | 28 | 17 | TX/CU | 36000 | 6450 | | | | | | |
| +50 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | NX | 100 | |
| | | | | | | | | | | | 14-15 | NX | 100 | |
| +40 | | | | | | | | | | | | | | |
| | | | | | | | | | | | 18 | NX | 100 | |
| | | | | | | | | | | | 40 | NX | 60 | |
| +30 | | | | | | | | | | | 14 | NX | 100 | |
| | | | | | | | | | | | 22 | NX | 100 | |
| +20 | | | | | | | | | | | 20 | NX | 80 | |
| | | | | | | | | | | | 24 | NX | 100 | |
| +10 | | | | | | | | | | | 28 | NX | 100 | |
| | | | | | | | | | | | 18<br>21<br>22<br>21<br>20 | NX | 100 | |
| 0 | | | | | | | | | | | | NX | 100 | |
| -10 | | | | | | | | | | | | | | |

ELEVATION +149



ASPHALTIC CONCRETE 2", CONCRETE 4"

DARK BROWN-GRAY FINE SAND (DUNE SAND)(FILL)

BROWN SILTY FINE SAND WITH RED-BROWN MOTTLING (COLMA FORMATION)(MEDIUM DENSE)

(WATER LEVEL, 11/15/78)

DARK YELLOW-BROWN CLAYEY FINE SAND WITH ORANGE IRON OXIDE MOTTLING AND TRACE OF BLACK DECAYED VEGETATION (DENSE)

DARK GRAY TO BLACK SHALE, HIGHLY BRECCIATED, IN DARK GRAY CLAY MATRIX; MODERATELY WEATHERED; WEAK; WITH CLASTS OF SILTSTONE, GRAYWACKE AND SERPENTINE.
(HIGH SUSCEPTIBILITY TO SLAKING)

GRAY TO BLACK SILTSTONE, BRECCIATED, WITH BLACK SLICKENSIDED SHALE INTERBEDS. SLIGHTLY WEATHERED, MODERATELY STRONG.

GRAY GRAYWACKE, OCCASIONAL CALCITE VEINLETS, SHEARED SHALE INTERBEDS SLIGHTLY WEATHERED, STRONG.
(SHEAR ZONE AT EL. +34')

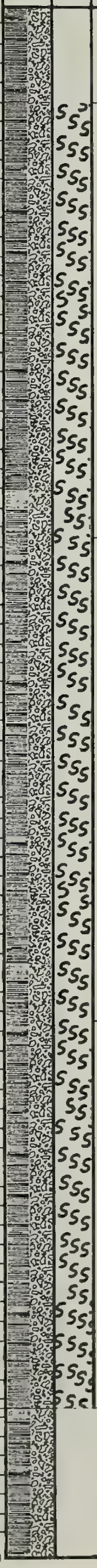
NOTES:
1. SAMPLING RESISTANCE:
   U DRIVEN BY 265# SLIPJARS FALLING 21"
2. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED ON NEARBY SURVEYED BENCH MARKS.
3. REFER TO FOLLOWING GEOLOGIC LOGS FOR A MORE DETAILED DESCRIPTION OF THE BEDROCK.
4. *SWELL TESTS AND CLAY MINEROLOGY TESTS

# LOG OF BORING

**DAMES & MOORE**

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 27
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION EL CAMINO DEL MAR NEAR 30th. AVE.
ELEV. 149
PAGE 1 OF 5

| ROCK TYPE | WEATHERING (SEE BELOW) | STRENGTH (SEE BELOW) | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | GRAPHIC LOG | FRACTURE ORIENTATION | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | RQD 75 50 25 | FRACTURES PER FOOT 1 4 16 64 | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 74 | | | | | | | | |
| SHALE BRECCIATED | | | DARK GRAY TO BLACK HIGHLY BRECCIATED AND SHEARED, WITH SAND TO GRAVEL SIZED CLASTS OF SILTSTONE AND GRAYWACKE | 74 | | | | | SHEAR ZONE<br>MADE COHESIVE BY CLAY MATRIX | | | | RUN #1<br>DP=0 PSI<br>DIAMOND BIT |
| | | | | | 76 | | | | | | | | |
| | | | | 72 | | | | 100 | | | | 10-12 MIN/FT | |
| | | | | | 78 | | | | SLICKENSIDED SHALE, HIGH SUSCEPTIBILITY TO SLAKING | | | | |
| | | | | 70 | | | | | | | | | |
| | | | | | 80 | | | | | | | | RUN #2<br>DP=0 PSI |
| | | | | 68 | | | | | | | | | |
| | | | | | 82 | | | 100 | MODERATE SUSCEPTIBILITY TO SLAKING | | | 10-12 MIN/FT | |
| | | | | 66 | | | | | | | | | |
| | | | | | 84 | | | | | | | | RUN #3<br>DP=0 PSI |
| | | | | 64 | | | | | | | | | |
| | | | | | 86 | | | 100 | | | | 10-12 MIN/FT | |
| | | | | 62 | | | | | | | | | |
| | | | SOME CLASTS OF SERPENTINE | | 88 | | | | SLICKENSIDED SHALE, HIGH SUSCEPTIBILITY TO SLAKING | | | | |
| | | | | 60 | | | | | | | | | 1.5' TRICONE DRILLING |
| | | | | | 90 | | | | | | | | |



FR
SW
MW
HW
XW

VW
W
MS
S
VS

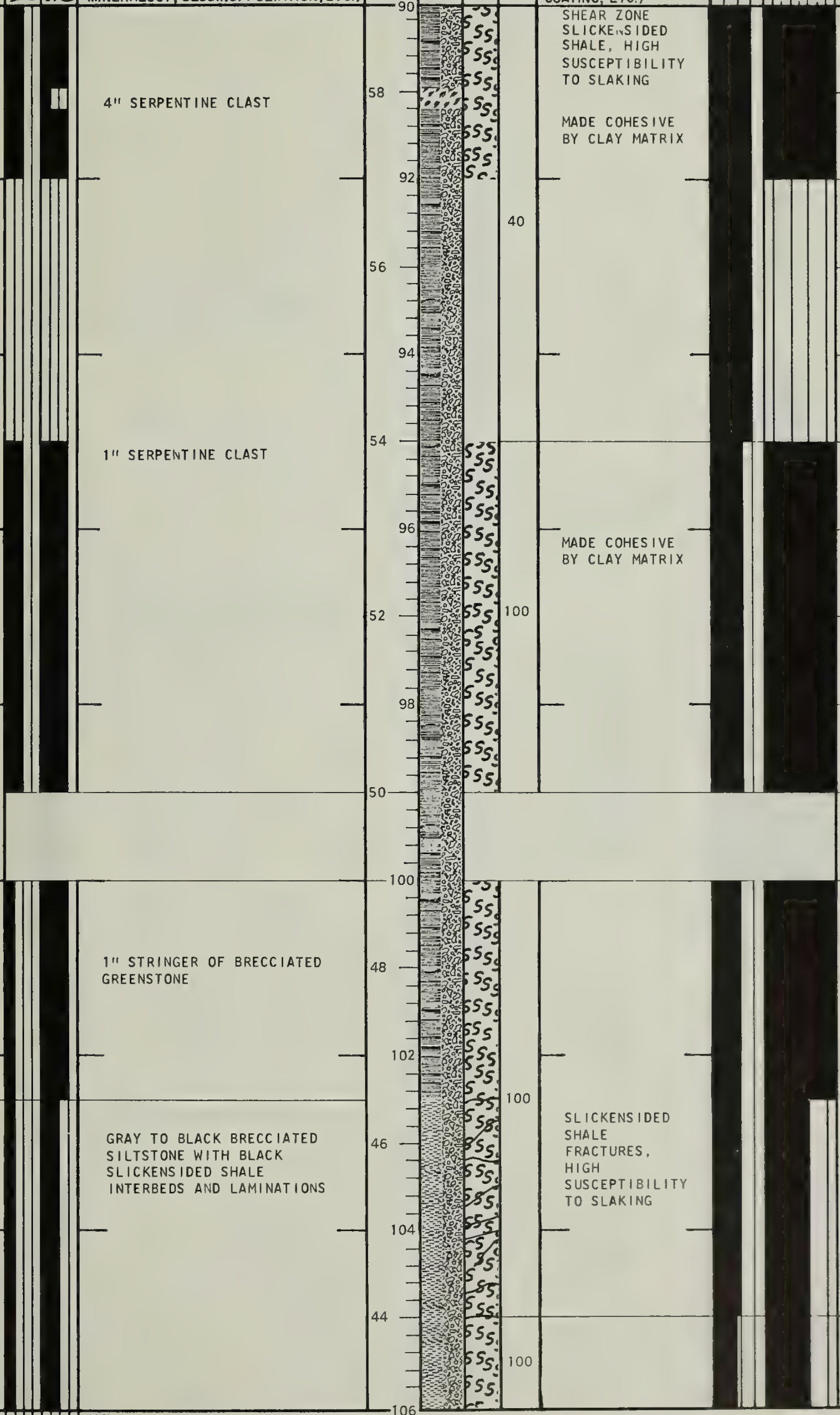
# LOG OF BORING

DAMES & MOORE

PLATE A-IAA/I

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 27
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION EL CAMINO DEL MAR NEAR 30th. AVE.
ELEV. 149
PAGE 2 OF 5

| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| SHALE BRECCIATED | 4" SERPENTINE CLAST | 58 | 90 | | SHEAR ZONE SLICKENSIDED SHALE, HIGH SUSCEPTIBILITY TO SLAKING<br>MADE COHESIVE BY CLAY MATRIX | 15<br>15 | RUN #4<br>DP=0 PSI |
| | | 56 | 92 | 40 | | 14<br>20 | |
| | | | 94 | | | 16 | |
| | 1" SERPENTINE CLAST | 54 | | | | 14 | RUN #5<br>DP=0 PSI |
| | | 52 | 96 | 100 | MADE COHESIVE BY CLAY MATRIX | 12<br>14 | |
| | | | 98 | | | 15 | |
| | | 50 | | | | - | 1' TRICONE DRILLING |
| | 1" STRINGER OF BRECCIATED GREENSTONE | 48 | 100 | | | | RUN #6<br>DP=100 PSI |
| | | | 102 | 100 | | - | |
| SILTSTONE BRECCIATED | GRAY TO BLACK BRECCIATED SILTSTONE WITH BLACK SLICKENSIDED SHALE INTERBEDS AND LAMINATIONS | 46 | | | SLICKENSIDED SHALE FRACTURES, HIGH SUSCEPTIBILITY TO SLAKING | | |
| | | 44 | 104 | | | | |
| | | | | 100 | | - | RUN #7 |
| | | | 106 | | | | |



FR
SW
MW
HW
XW

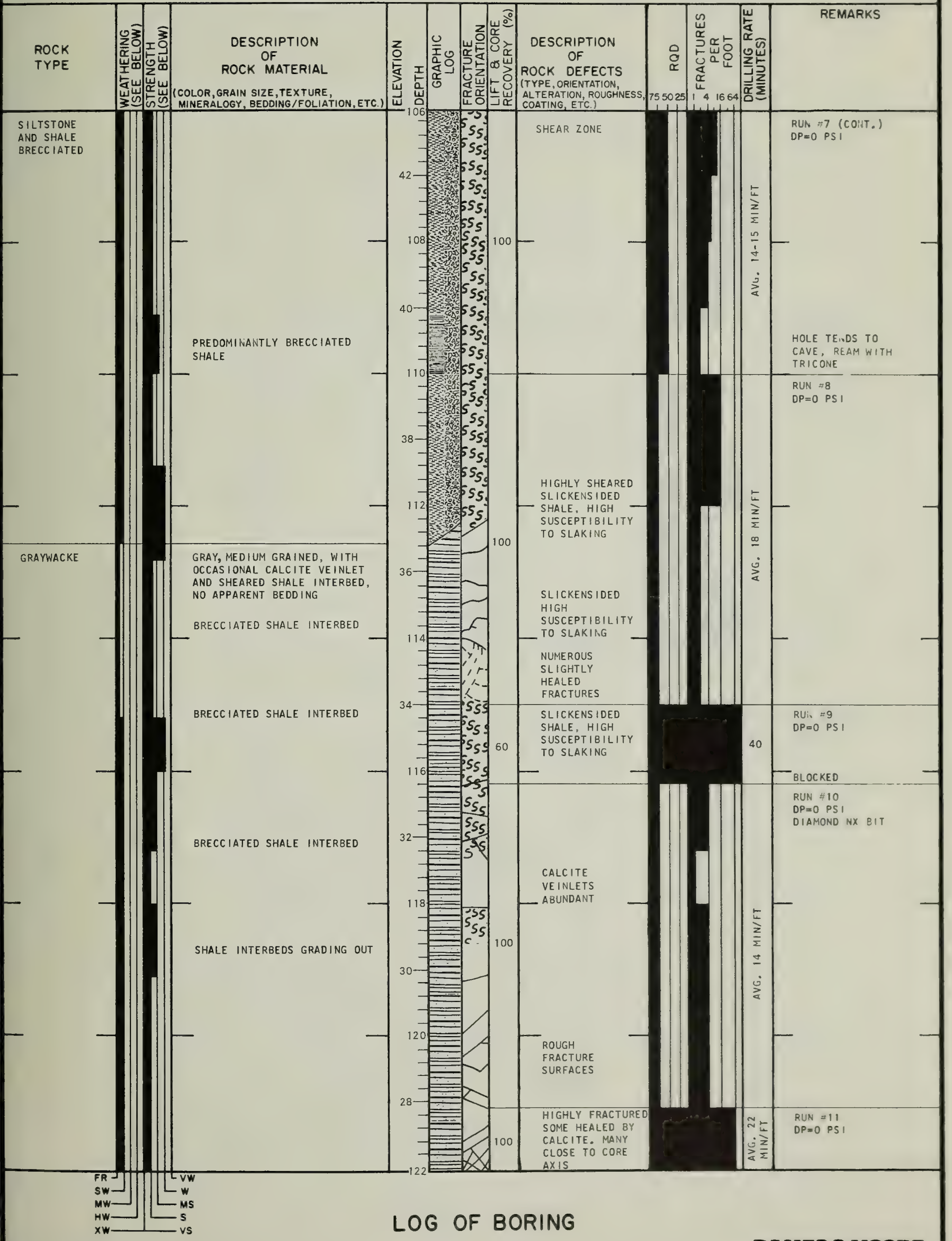
VW
W
MS
S
VS

## LOG OF BORING

**DAMES & MOORE**

PLATE A-1AA/2

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 27
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION EL CAMINO DEL MAR NEAR 30th. AVE.
ELEV. 149
PAGE 3 OF 5



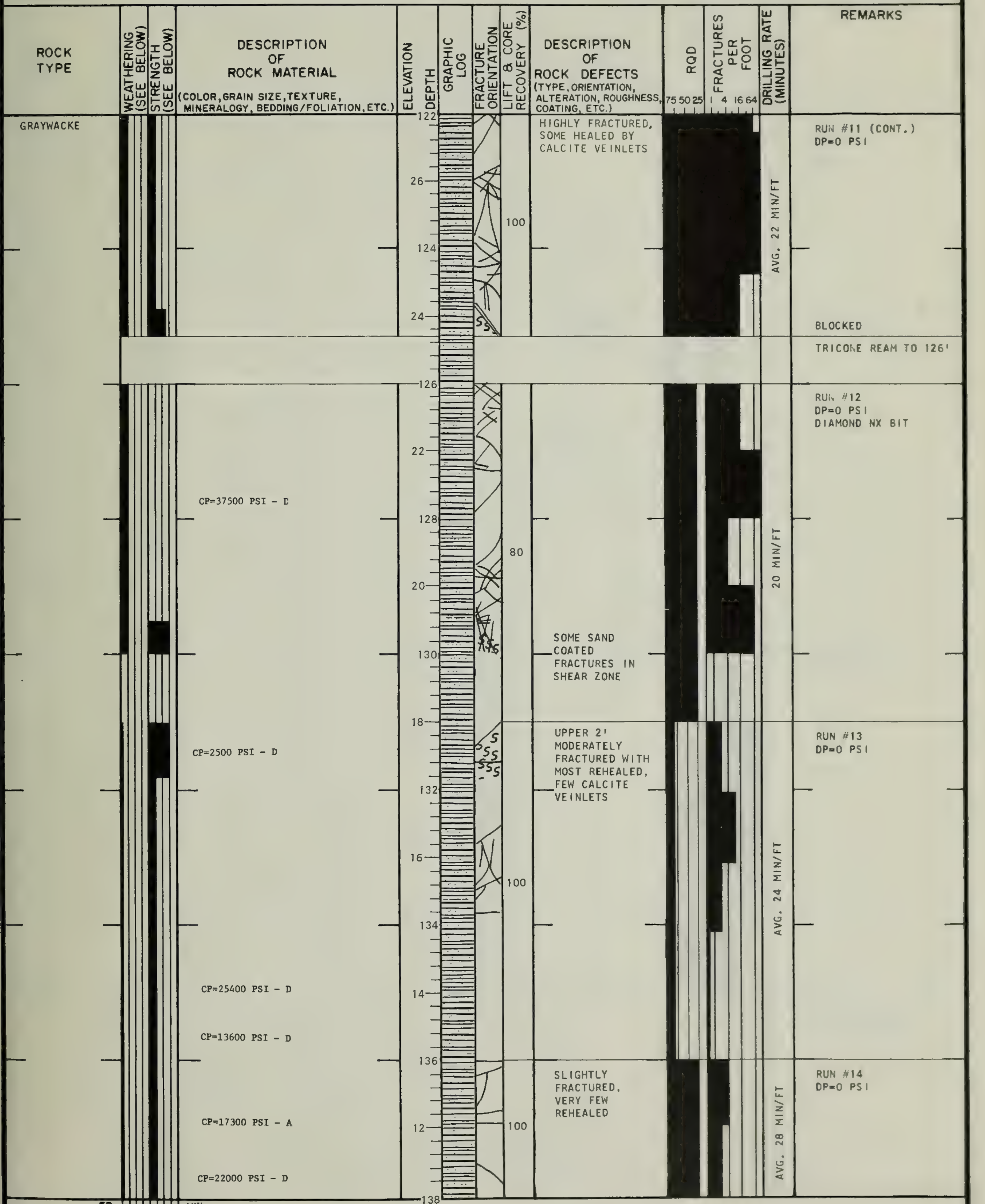
| Depth | Rock Type | Description of Rock Material | Lift & Core Recovery (%) | Description of Rock Defects | Drilling Rate (Minutes) | Remarks |
|---|---|---|---|---|---|---|
| 106–110 | SILTSTONE AND SHALE BRECCIATED | PREDOMINANTLY BRECCIATED SHALE | 100 | SHEAR ZONE | AVG. 14-15 MIN/FT | RUN #7 (CONT.)<br>DP=0 PSI<br>HOLE TENDS TO CAVE, REAM WITH TRICONE |
| 110–115 | GRAYWACKE | GRAY, MEDIUM GRAINED, WITH OCCASIONAL CALCITE VEINLET AND SHEARED SHALE INTERBED, NO APPARENT BEDDING<br>BRECCIATED SHALE INTERBED | 100 | HIGHLY SHEARED SLICKENSIDED SHALE, HIGH SUSCEPTIBILITY TO SLAKING<br>SLICKENSIDED HIGH SUSCEPTIBILITY TO SLAKING<br>NUMEROUS SLIGHTLY HEALED FRACTURES | AVG. 18 MIN/FT | RUN #8<br>DP=0 PSI |
| 115–116 | | BRECCIATED SHALE INTERBED | 60 | SLICKENSIDED SHALE, HIGH SUSCEPTIBILITY TO SLAKING | 40 | RUN #9<br>DP=0 PSI<br>BLOCKED |
| 116–121 | | BRECCIATED SHALE INTERBED<br>SHALE INTERBEDS GRADING OUT | 100 | CALCITE VEINLETS ABUNDANT<br>ROUGH FRACTURE SURFACES | AVG. 14 MIN/FT | RUN #10<br>DP=0 PSI<br>DIAMOND NX BIT |
| 121–122 | | | 100 | HIGHLY FRACTURED SOME HEALED BY CALCITE, MANY CLOSE TO CORE AXIS | AVG. 22 MIN/FT | RUN #11<br>DP=0 PSI |

# LOG OF BORING

**DAMES & MOORE**

PLATE A-1AA/3

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 27
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION EL CAMINO DEL MAR NEAR 30th. AVE.
ELEV. 149
PAGE 4 OF 5



GRAYWACKE

CP=37500 PSI - D

CP=2500 PSI - D

CP=25400 PSI - D

CP=13600 PSI - D

CP=17300 PSI - A

CP=22000 PSI - D

HIGHLY FRACTURED, SOME HEALED BY CALCITE VEINLETS

SOME SAND COATED FRACTURES IN SHEAR ZONE

UPPER 2' MODERATELY FRACTURED WITH MOST REHEALED, FEW CALCITE VEINLETS

SLIGHTLY FRACTURED, VERY FEW REHEALED

RUN #11 (CONT.)
DP=0 PSI

BLOCKED

TRICONE REAM TO 126'

RUN #12
DP=0 PSI
DIAMOND NX BIT

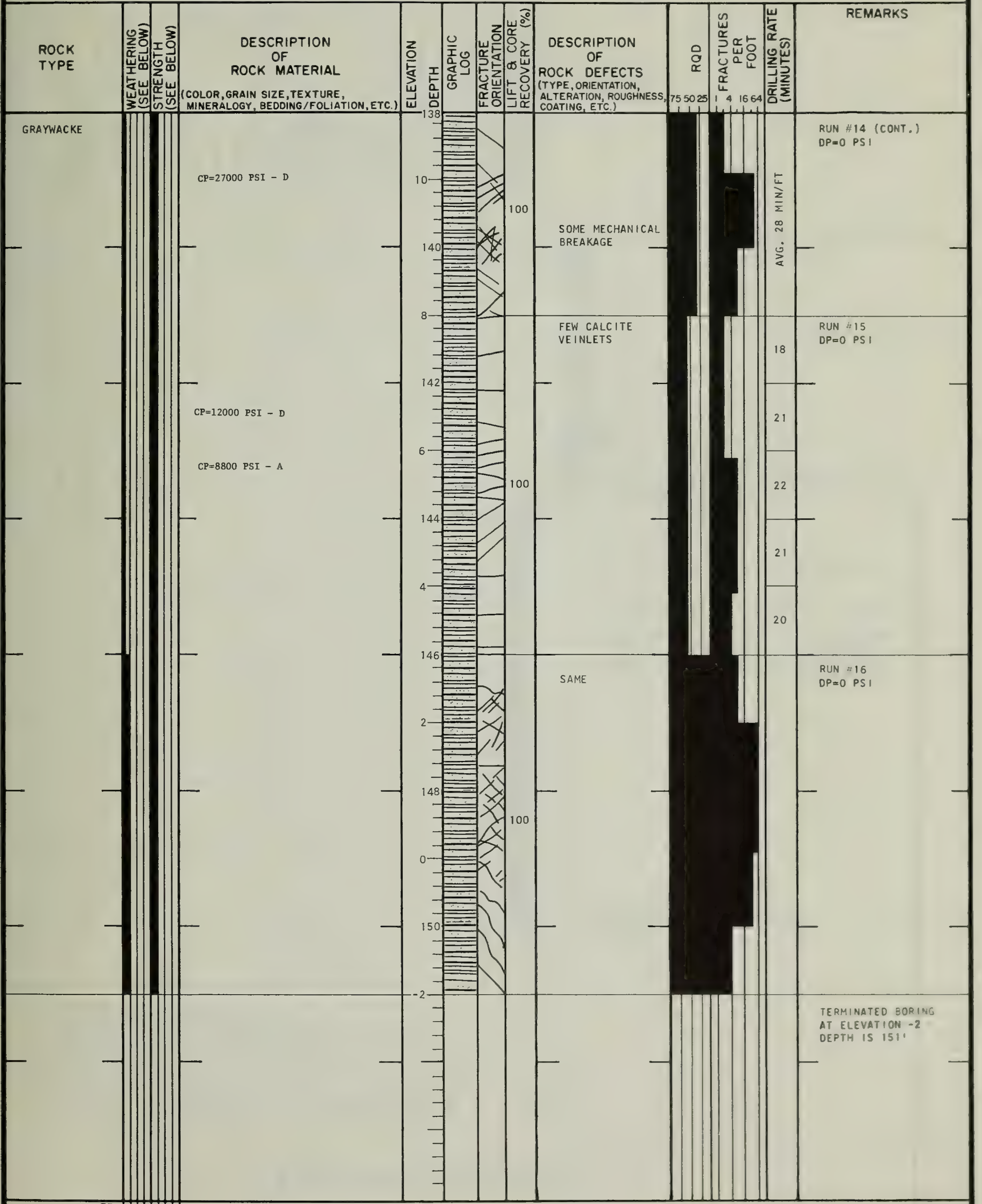
RUN #13
DP=0 PSI

RUN #14
DP=0 PSI

# LOG OF BORING

DAMES & MOORE

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 27
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION EL CAMINO DEL MAR NEAR 30th. AVE.
ELEV. 149
PAGE 5 OF 5



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|
| GRAYWACKE | CP=27000 PSI - D | 138–141 | 100 | SOME MECHANICAL BREAKAGE | AVG. 28 MIN/FT | RUN #14 (CONT.)<br>DP=0 PSI |
| | CP=12000 PSI - D<br>CP=8800 PSI - A | 141–146 | 100 | FEW CALCITE VEINLETS | 18<br>21<br>22<br>21<br>20 | RUN #15<br>DP=0 PSI |
| | | 146–151 | 100 | SAME | | RUN #16<br>DP=0 PSI |
| | | 151 | | | | TERMINATED BORING AT ELEVATION -2 DEPTH IS 151' |

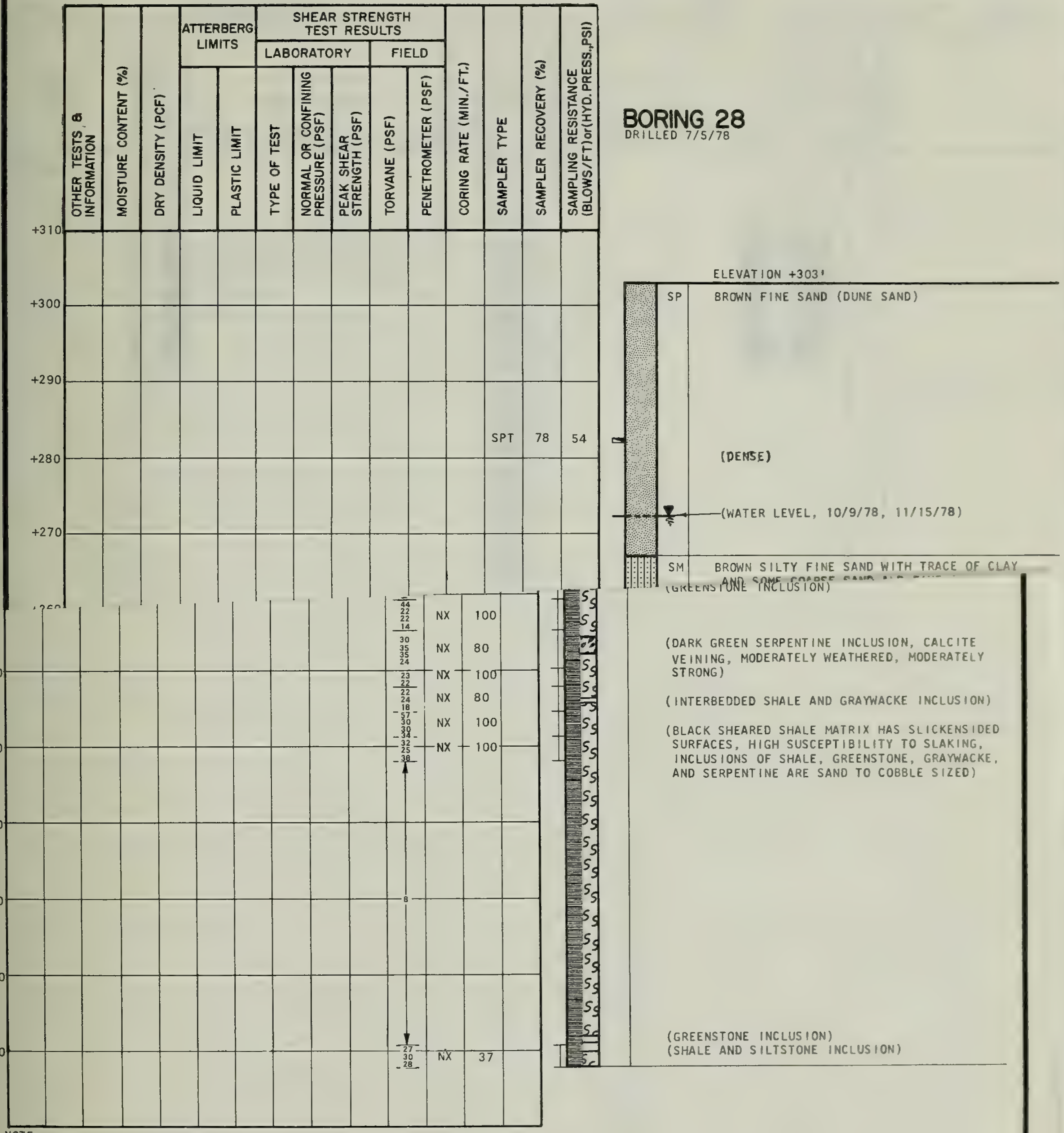
FR — SW — MW — HW — XW
VW — W — MS — S — VS

LOG OF BORING

DAMES & MOORE

PLATE A-IAA/5

## BORING 28
DRILLED 7/5/78



| OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS |  | SHEAR STRENGTH TEST RESULTS |  |  |  |  | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD.PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | LABORATORY |  |  | FIELD |  |  |  |  |  |
|  |  |  | LIQUID LIMIT | PLASTIC LIMIT | TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | TORVANE (PSF) | PENETROMETER (PSF) |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  | SPT | 78 | 54 |
|  |  |  |  |  |  |  |  |  |  | 44<br>22<br>22<br>14 | NX | 100 |  |
|  |  |  |  |  |  |  |  |  |  | 30<br>35<br>35<br>24 | NX | 80 |  |
|  |  |  |  |  |  |  |  |  |  | 23<br>22 | NX | 100 |  |
|  |  |  |  |  |  |  |  |  |  | 22<br>24<br>18 | NX | 80 |  |
|  |  |  |  |  |  |  |  |  |  | 57<br>30<br>30<br>34 | NX | 100 |  |
|  |  |  |  |  |  |  |  |  |  | 32<br>25<br>38 | NX | 100 |  |
|  |  |  |  |  |  |  |  |  |  | 8 |  |  |  |
|  |  |  |  |  |  |  |  |  |  | 27<br>30<br>28 | NX | 37 |  |

ELEVATION +303'

SP BROWN FINE SAND (DUNE SAND)

(DENSE)

(WATER LEVEL, 10/9/78, 11/15/78)

SM BROWN SILTY FINE SAND WITH TRACE OF CLAY
AND SOME

(GREENSTONE INCLUSION)

(DARK GREEN SERPENTINE INCLUSION, CALCITE VEINING, MODERATELY WEATHERED, MODERATELY STRONG)

(INTERBEDDED SHALE AND GRAYWACKE INCLUSION)

(BLACK SHEARED SHALE MATRIX HAS SLICKENSIDED SURFACES, HIGH SUSCEPTIBILITY TO SLAKING, INCLUSIONS OF SHALE, GREENSTONE, GRAYWACKE, AND SERPENTINE ARE SAND TO COBBLE SIZED)

(GREENSTONE INCLUSION)
(SHALE AND SILTSTONE INCLUSION)

NOTE:
1. SAMPLING RESISTANCE:
   SPT DRIVEN WITH 140# HAMMER FALLING 30"
2. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED ON CONSTRUCTION DRAWINGS FOR THE LEGION OF HONOR FOUNTAIN, APPROXIMATE 800' AWAY.
3. SEE FOLLOWING GEOLOGIC LOGS FOR A MORE DETAILED DESCRIPTION OF THE BEDROCK.
4. THE EXCELLENT CORE RECOVERY IS NOT INDICATIVE OF SOUND ROCK CONDITIONS, BUT RATHER EXEMPLARY SKILL AND CARE ON THE PART OF THE DRILLER.

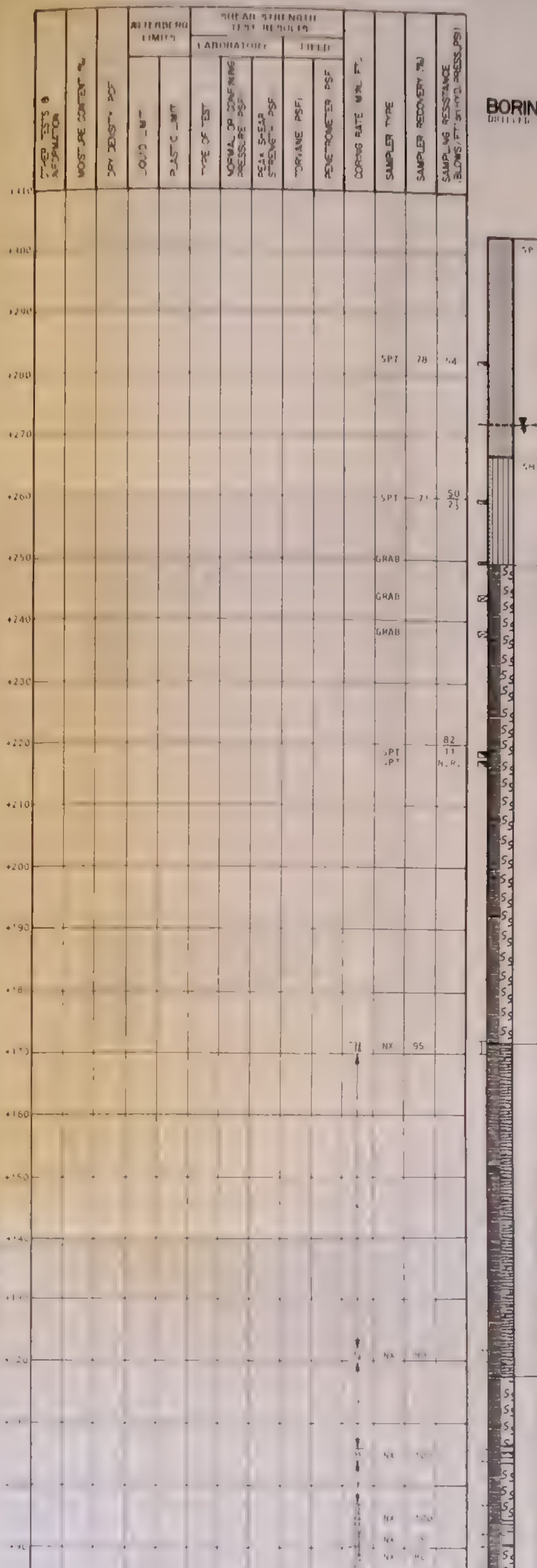
# LOG OF BORING

**DAMES & MOORE**

PLATE A-IAB

## BORING 28

DRILLED 7/5/78



ELEVATION +303'

SP BROWN FINE SAND (DUNE SAND)

(DENSE)

(WATER LEVEL, 10/9/78, 11/15/78)

SM BROWN SILTY FINE SAND WITH TRACE OF CLAY AND SOME COARSE SAND AND FINE GRAVEL (COLMA FORMATION)
(DENSE AND PARTIALLY CEMENTED,

GRAY SHEARED SHALE (FRANCISCAN MELANGE) WEATHERED TO A CLAY, WITH GREEN AND RED-BROWN FRAGMENTS OF GREENSTONE AND SERPENTINE, VERY WEAK
(GRADING MODERATELY WEATHERED)

(SERPENTINIZED BLACK SHALE, FRESH, VERY WEAK

(GRAYWACKE INCLUSIONS IN A BLACK SHEARED SHALE MATRIX)

(GREENSTONE AND SERPENTINE INCLUSIONS IN A BLACK SHEARED SHALE MATRIX)

(SERPENTINE INCLUSIONS)

GREEN TO RED-BROWN GREENSTONE (MAJOR INCLUSION IN A SHEARED SHALE MATRIX) FINE-GRAINED NUMEROUS CALCITE VEINS HIGHLY FRACTURED WITH CLAY INFILLING, RQD = 0 TO 25 SLIGHTLY WEATHERED, MODERATELY STRONG TO STRONG SLICKENSIDED SURFACES.

BLACK TO BROWN SHEARED SHALE AND SILTSTONE MELANGE FRESH VERY WEAK HIGH SUSCEPTIBILITY TO SLAKING WITH NUMEROUS INCLUSION OF SILTSTONE, GREENSTONE SHALE AND QUARTZ FROM SAND TO COBBLE SIZE

(SILTSTONE INCLUSION)

(GREENSTONE INCLUSION)

(SHEARED SHALE MATRIX GRADING WITH SAND TO PEBBLE-SIZE GRAYWACKE INCLUSIONS)

(GRAYWACKE INCLUSION, HIGHLY FRACTURED MODERATELY WEATHERED MODERATELY WEAK)
(GRAYWACKE INCLUSION, SLIGHTLY WEATHERED STRONG)

(GRAYWACKE INCLUSION HIGHLY WEATHERED MODERATELY STRONG NUMEROUS CLAY FILLED FRACTURES)

(GRAYWACKE INCLUSION SLIGHTLY WEATHERED STRONG)
(GRAYWACKE INCLUSION SLIGHTLY WEATHERED STRONG)
(SHEARED SHALE MATRIX GRADING SERPENTINIZED, VERY WEAK WITH SERPENTINE INCLUSIONS)
(SERPENTINE GRADING OUT NUMEROUS INCLUSIONS OF GREENSTONE SHALE AND GRAYWACKE MINOR VEINS OF CALCITE)

(RED TO RED-BROWN GREENSTONE INCLUSION BRECCIATED MODERATELY WEATHERED MODERATELY STRONG)
(GRAY GRAYWACKE INCLUSION)
(BLACK SHEARED SHALE MATRIX GRADING WITH PREDOMINATELY GRAYWACKE INCLUSION FRESH, WEAK)

(GRAYWACKE INCLUSION)

(SHEARED SHALE MATRIX GRADING SERPENTINIZED WITH GREENSTONE GRAYWACKE AND SHALE CLASTS)

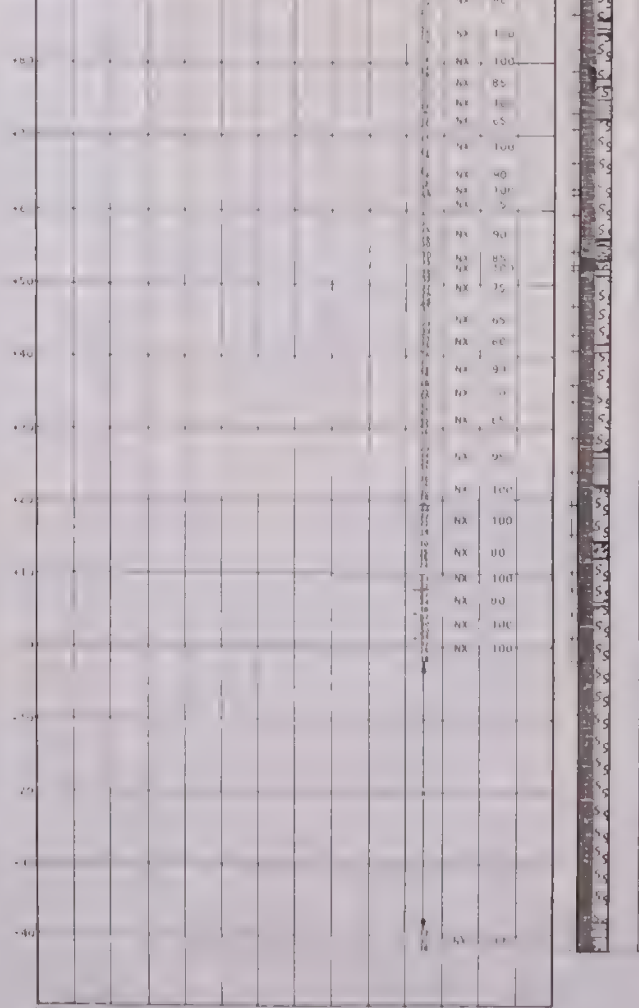
(GRAY GRAYWACKE AND INTERBEDDED BLACK SHALE INCLUSION CONTORTED AND BRECCIATED SLIGHTLY WEATHERED STRONG)
(GREENSTONE INCLUSION)

(DARK GREEN SERPENTINE INCLUSION CALCITE VEINING, MODERATELY WEATHERED MODERATELY STRONG)

(INTERBEDDED SHALE AND GRAYWACKE INCLUSION)

(BLACK SHEARED SHALE MATRIX HAS SLICKENSIDED SURFACES HIGH SUSCEPTIBILITY TO SLAKING INCLUSIONS OF SHALE GREENSTONE GRAYWACKE AND SERPENTINE ARE SAND TO COBBLE SIZED)

(GREENSTONE INCLUSION)
(SHALE AND SILTSTONE INCLUSION)



NOTES

1 [illegible]
2 ELEVATION [illegible] CONSTRUCTION [illegible] FOUNTAIN APPROXIMATELY [illegible] AWAY
3 SEE [illegible] LOG [illegible] DESCRIPTION [illegible]
4 THE [illegible] CORE RECOVERY [illegible] NOT INDICATIVE OF SOUND ROCK [illegible] AND CARE ON THE PART [illegible]

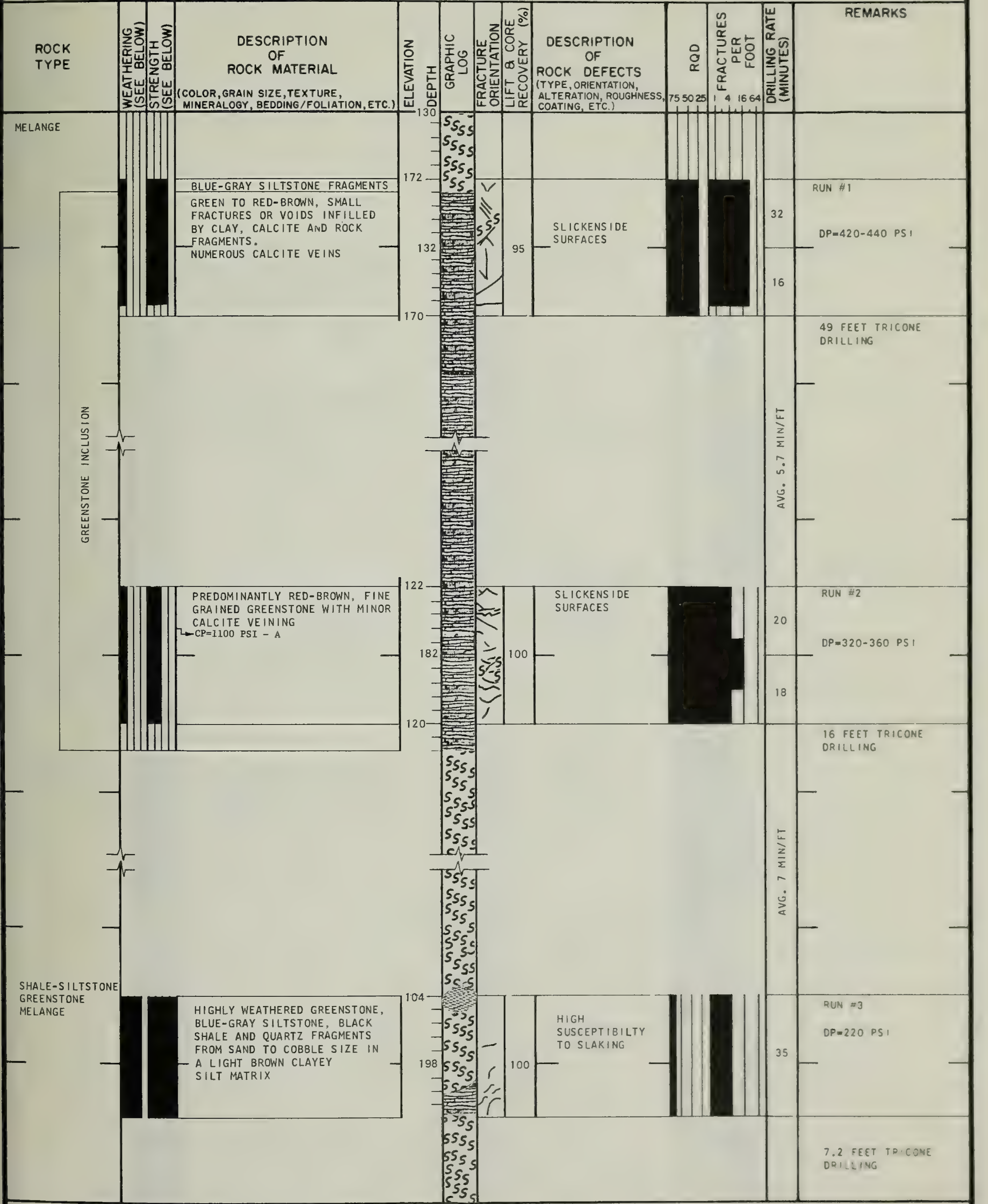
# LOG OF BORING

DAMES & MOORE

PLATE A-IAB

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
PROJECT: RICHMOND TRANSPORT SEWER
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION: LINCOLN PARK
ELEV. 303

BORING NO. 28
ANGLE FROM HORIZONTAL 90°
PAGE 1 OF 8



| ROCK TYPE | ELEVATION | DEPTH | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| MELANGE | | 130 | | | | | |
| GREENSTONE INCLUSION | 172 – 170 | 132 | BLUE-GRAY SILTSTONE FRAGMENTS<br>GREEN TO RED-BROWN, SMALL FRACTURES OR VOIDS INFILLED BY CLAY, CALCITE AND ROCK FRAGMENTS.<br>NUMEROUS CALCITE VEINS | 95 | SLICKENSIDE SURFACES | 32<br>16 | RUN #1<br>DP=420-440 PSI |
| | | | | | | AVG. 5.7 MIN/FT | 49 FEET TRICONE DRILLING |
| | 122 – 120 | 182 | PREDOMINANTLY RED-BROWN, FINE GRAINED GREENSTONE WITH MINOR CALCITE VEINING<br>CP=1100 PSI - A | 100 | SLICKENSIDE SURFACES | 20<br>18 | RUN #2<br>DP=320-360 PSI |
| | | | | | | AVG. 7 MIN/FT | 16 FEET TRICONE DRILLING |
| SHALE-SILTSTONE GREENSTONE MELANGE | 104 | 198 | HIGHLY WEATHERED GREENSTONE, BLUE-GRAY SILTSTONE, BLACK SHALE AND QUARTZ FRAGMENTS FROM SAND TO COBBLE SIZE IN A LIGHT BROWN CLAYEY SILT MATRIX | 100 | HIGH SUSCEPTIBILTY TO SLAKING | 35 | RUN #3<br>DP=220 PSI |
| | | | | | | | 7.2 FEET TRICONE DRILLING |

FR SW MW HW XW

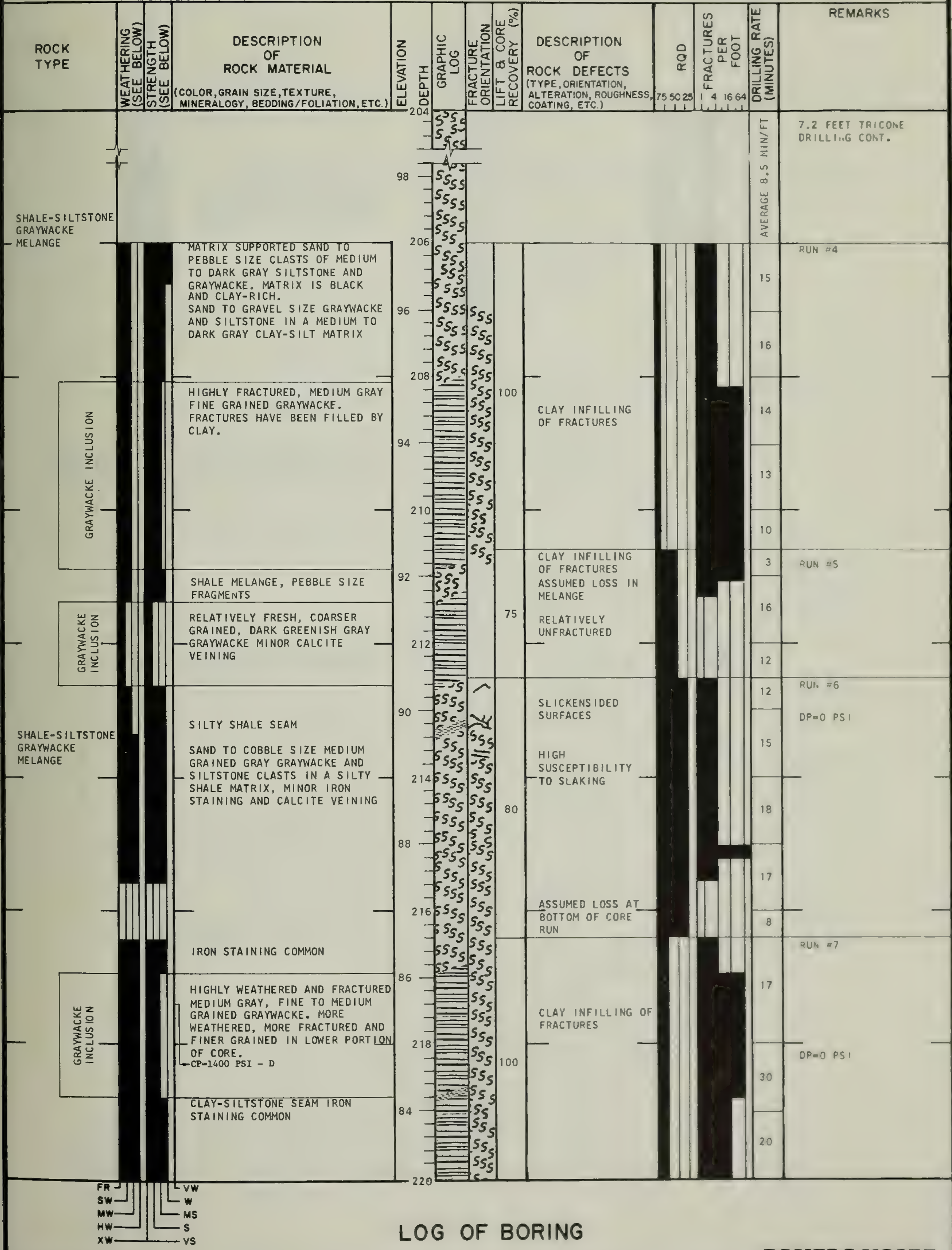
VW W MS S VS

LOG OF BORING

DAMES & MOORE

PLATE A-1AB/1

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 28
PROJECT: RICHMOND TRANSPORT SEWER
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
ANGLE FROM HORIZONTAL 90°
LOCATION LINCOLN PARK
ELEV. 303
PAGE 2 OF 8



MATRIX SUPPORTED SAND TO PEBBLE SIZE CLASTS OF MEDIUM TO DARK GRAY SILTSTONE AND GRAYWACKE. MATRIX IS BLACK AND CLAY-RICH.
SAND TO GRAVEL SIZE GRAYWACKE AND SILTSTONE IN A MEDIUM TO DARK GRAY CLAY-SILT MATRIX

HIGHLY FRACTURED, MEDIUM GRAY FINE GRAINED GRAYWACKE. FRACTURES HAVE BEEN FILLED BY CLAY.

SHALE MELANGE, PEBBLE SIZE FRAGMENTS

RELATIVELY FRESH, COARSER GRAINED, DARK GREENISH GRAY GRAYWACKE MINOR CALCITE VEINING

SILTY SHALE SEAM

SAND TO COBBLE SIZE MEDIUM GRAINED GRAY GRAYWACKE AND SILTSTONE CLASTS IN A SILTY SHALE MATRIX, MINOR IRON STAINING AND CALCITE VEINING

IRON STAINING COMMON

HIGHLY WEATHERED AND FRACTURED MEDIUM GRAY, FINE TO MEDIUM GRAINED GRAYWACKE. MORE WEATHERED, MORE FRACTURED AND FINER GRAINED IN LOWER PORTION OF CORE.
CP=1400 PSI - D

CLAY-SILTSTONE SEAM IRON STAINING COMMON

CLAY INFILLING OF FRACTURES

CLAY INFILLING OF FRACTURES
ASSUMED LOSS IN MELANGE

RELATIVELY UNFRACTURED

SLICKENSIDED SURFACES

HIGH SUSCEPTIBILITY TO SLAKING

ASSUMED LOSS AT BOTTOM OF CORE RUN

CLAY INFILLING OF FRACTURES

7.2 FEET TRICONE DRILLING CONT.

RUN #4

RUN #5

RUN #6

DP=0 PSI

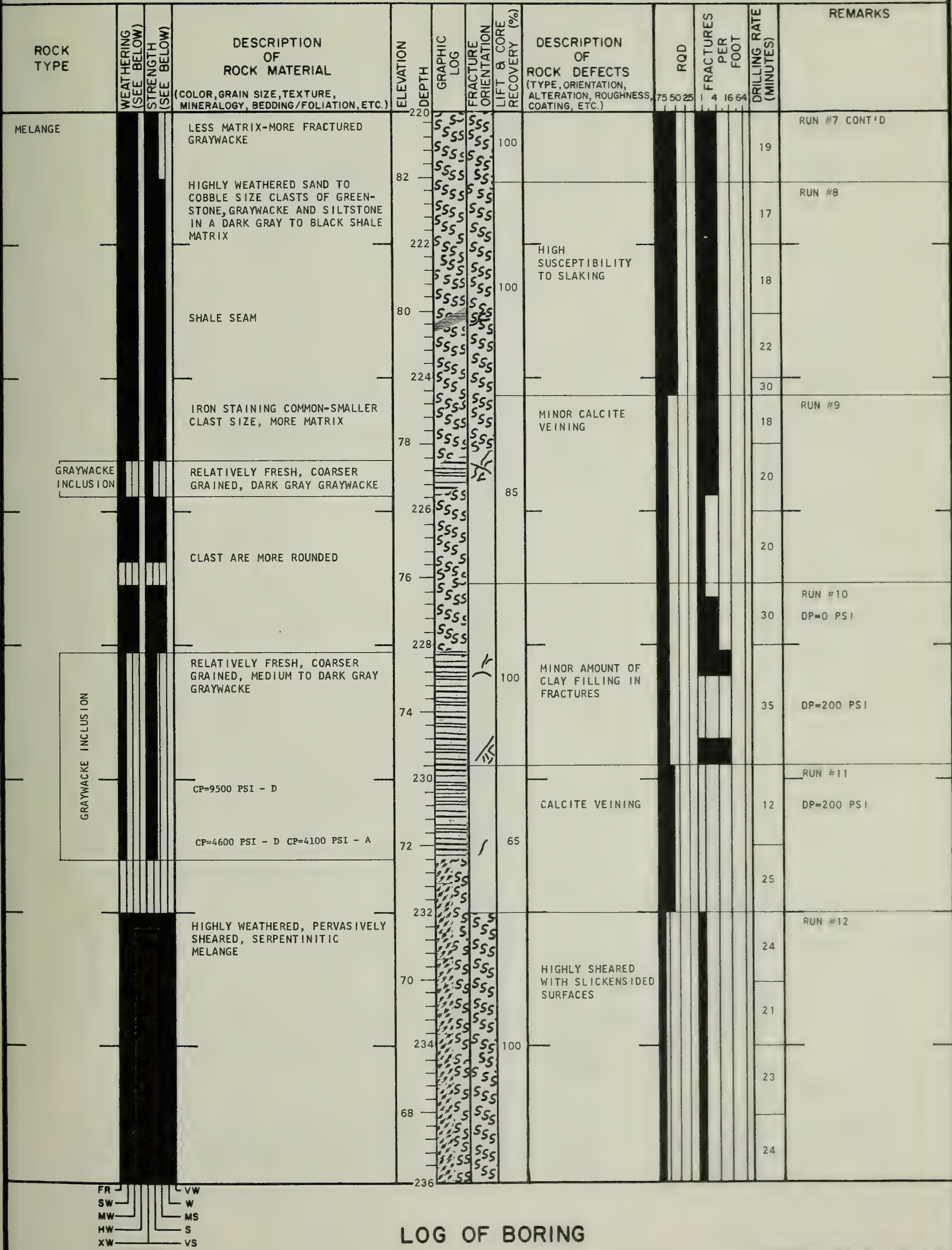
RUN #7

DP=0 PSI

# LOG OF BORING

**DAMES & MOORE**

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 28
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION LINCOLN PARK
ELEV. 303
PAGE 3 OF 8



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|
| MELANGE | LESS MATRIX-MORE FRACTURED GRAYWACKE | 100 | | 19 | RUN #7 CONT'D |
| | HIGHLY WEATHERED SAND TO COBBLE SIZE CLASTS OF GREENSTONE, GRAYWACKE AND SILTSTONE IN A DARK GRAY TO BLACK SHALE MATRIX | 100 | HIGH SUSCEPTIBILITY TO SLAKING | 17<br>18 | RUN #8 |
| | SHALE SEAM | | | 22<br>30 | |
| | IRON STAINING COMMON-SMALLER CLAST SIZE, MORE MATRIX | 85 | MINOR CALCITE VEINING | 18 | RUN #9 |
| GRAYWACKE INCLUSION | RELATIVELY FRESH, COARSER GRAINED, DARK GRAY GRAYWACKE | | | 20 | |
| | CLAST ARE MORE ROUNDED | | | 20 | |
| | | 100 | MINOR AMOUNT OF CLAY FILLING IN FRACTURES | 30 | RUN #10<br>DP=0 PSI |
| GRAYWACKE INCLUSION | RELATIVELY FRESH, COARSER GRAINED, MEDIUM TO DARK GRAY GRAYWACKE | | | 35 | DP=200 PSI |
| | CP=9500 PSI - D<br>CP=4600 PSI - D CP=4100 PSI - A | 65 | CALCITE VEINING | 12<br>25 | RUN #11<br>DP=200 PSI |
| | HIGHLY WEATHERED, PERVASIVELY SHEARED, SERPENTINITIC MELANGE | 100 | HIGHLY SHEARED WITH SLICKENSIDED SURFACES | 24<br>21<br>23<br>24 | RUN #12 |

## LOG OF BORING

DAMES & MOORE

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)

BORING NO. 28

PROJECT: RICHMOND TRANSPORT SEWER

ANGLE FROM HORIZONTAL 90°

DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY

LOCATION LINCOLN PARK

ELEV. 303

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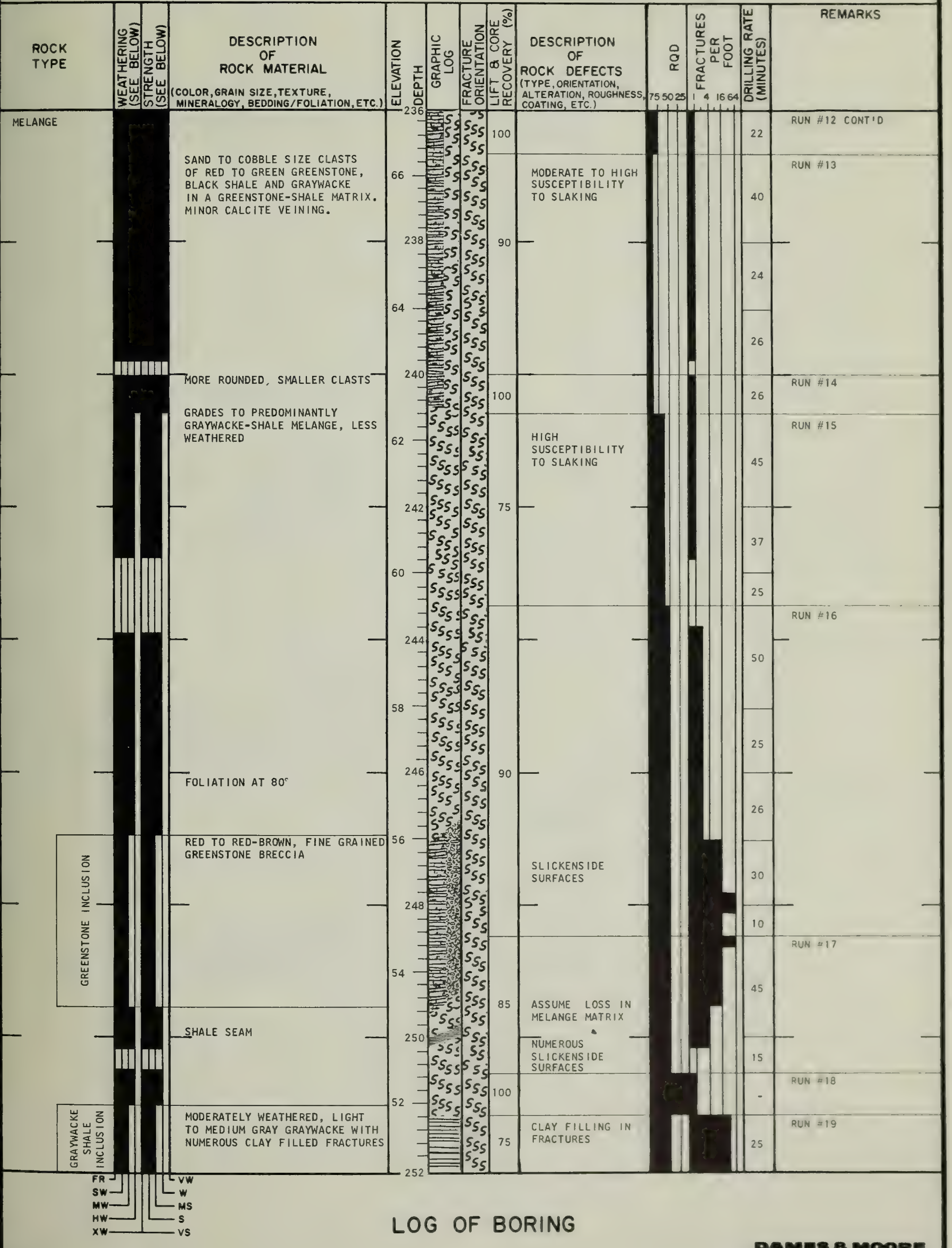


ROCK TYPE
WEATHERING (SEE BELOW)
STRENGTH (SEE BELOW)
DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.)
ELEVATION
DEPTH
GRAPHIC LOG
FRACTURE ORIENTATION
LIFT & CORE RECOVERY (%)
DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.)
RQD 75 50 25
FRACTURES PER FOOT 1 4 16 64
DRILLING RATE (MINUTES)
REMARKS
Elevation: 66, 64, 62, 60, 58, 56, 54, 52
Depth: 236, 238, 240, 242, 244, 246, 248, 250, 252
FR, SW, MW, HW, XW
VW, W, MS, S, VS

ROCK TYPE: MELANGE; GREENSTONE INCLUSION; GRAYWACKE SHALE INCLUSION

DESCRIPTION OF ROCK MATERIAL:

SAND TO COBBLE SIZE CLASTS OF RED TO GREEN GREENSTONE, BLACK SHALE AND GRAYWACKE IN A GREENSTONE-SHALE MATRIX. MINOR CALCITE VEINING.

MORE ROUNDED, SMALLER CLASTS

GRADES TO PREDOMINANTLY GRAYWACKE-SHALE MELANGE, LESS WEATHERED

FOLIATION AT 80°

RED TO RED-BROWN, FINE GRAINED GREENSTONE BRECCIA

SHALE SEAM

MODERATELY WEATHERED, LIGHT TO MEDIUM GRAY GRAYWACKE WITH NUMEROUS CLAY FILLED FRACTURES

LIFT & CORE RECOVERY (%): 100, 90, 100, 75, 90, 85, 100, 75

DESCRIPTION OF ROCK DEFECTS:

MODERATE TO HIGH SUSCEPTIBILITY TO SLAKING

HIGH SUSCEPTIBILITY TO SLAKING

SLICKENSIDE SURFACES

ASSUME LOSS IN MELANGE MATRIX

NUMEROUS SLICKENSIDE SURFACES

CLAY FILLING IN FRACTURES

DRILLING RATE (MINUTES): 22, 40, 24, 26, 26, 45, 37, 25, 50, 25, 26, 30, 10, 45, 15, -, 25

REMARKS:

RUN #12 CONT'D

RUN #13

RUN #14

RUN #15

RUN #16

RUN #17

RUN #18

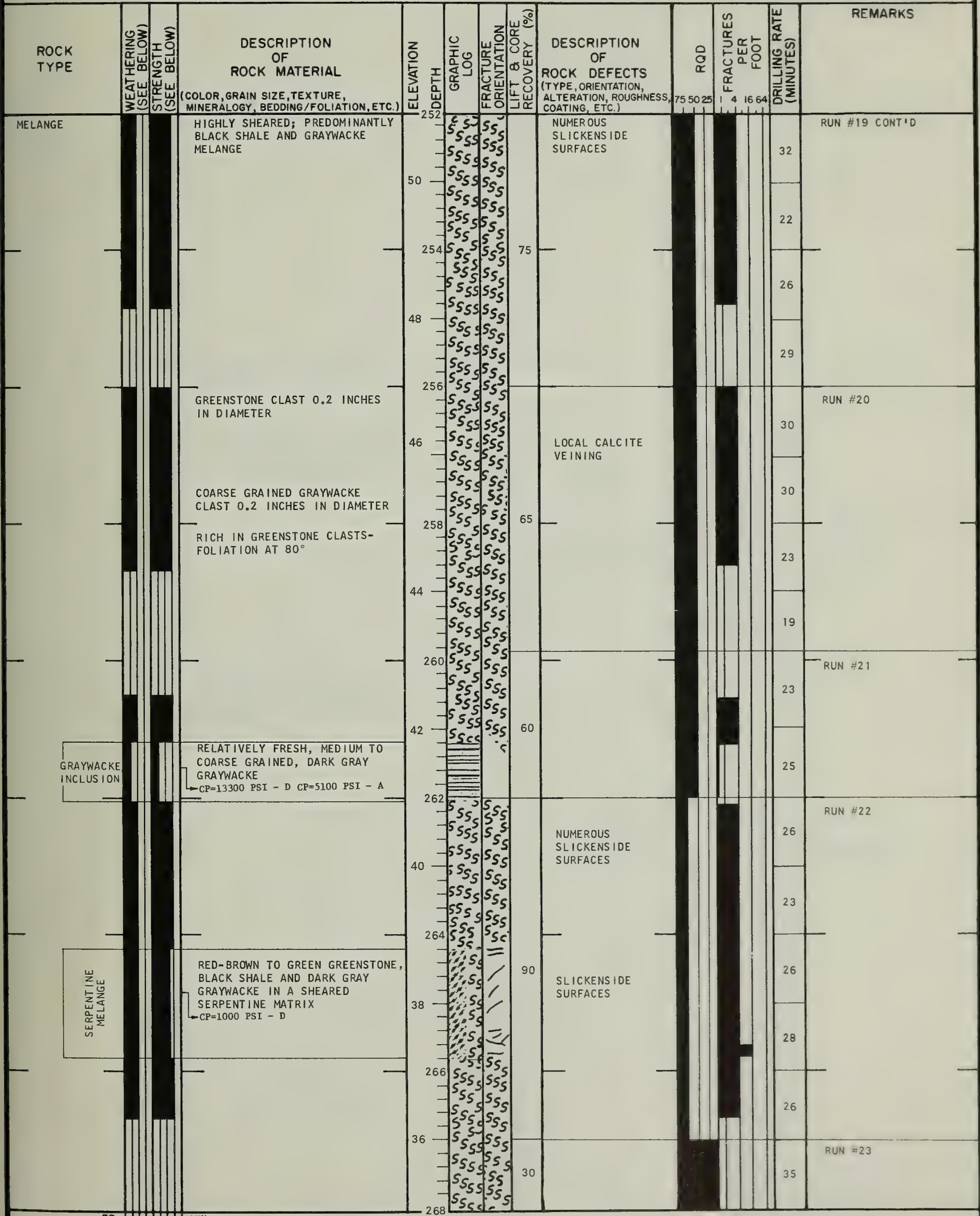
RUN #19

## LOG OF BORING

DAMES & MOORE

PLATE A-1AB/4

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 28
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION LINCOLN PARK
ELEV. 303
PAGE 5 OF 8



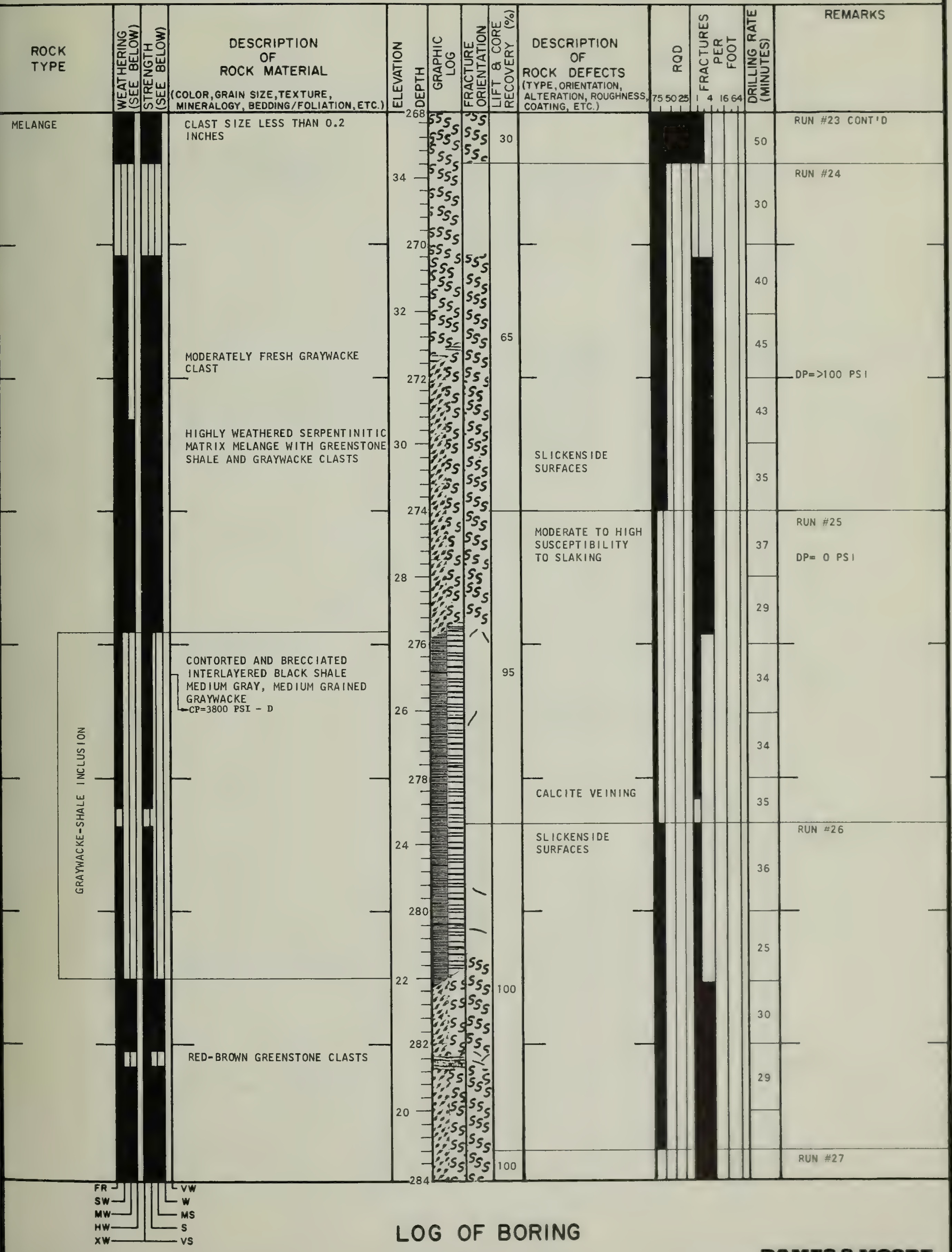
| DEPTH | ELEVATION | ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| 252 | | MELANGE | HIGHLY SHEARED; PREDOMINANTLY BLACK SHALE AND GRAYWACKE MELANGE | 75 | NUMEROUS SLICKENSIDE SURFACES | 32 | RUN #19 CONT'D |
| | 50 | | | | | 22 | |
| 254 | | | | | | 26 | |
| | 48 | | | | | 29 | |
| 256 | | | GREENSTONE CLAST 0.2 INCHES IN DIAMETER | 65 | | 30 | RUN #20 |
| | 46 | | COARSE GRAINED GRAYWACKE CLAST 0.2 INCHES IN DIAMETER | | LOCAL CALCITE VEINING | 30 | |
| 258 | | | RICH IN GREENSTONE CLASTS- FOLIATION AT 80° | | | 23 | |
| | 44 | | | | | 19 | |
| 260 | | | | 60 | | 23 | RUN #21 |
| | 42 | GRAYWACKE INCLUSION | RELATIVELY FRESH, MEDIUM TO COARSE GRAINED, DARK GRAY GRAYWACKE<br>CP=13300 PSI - D CP=5100 PSI - A | | | 25 | |
| 262 | | | | 90 | NUMEROUS SLICKENSIDE SURFACES | 26 | RUN #22 |
| | 40 | | | | | 23 | |
| 264 | | SERPENTINE MELANGE | RED-BROWN TO GREEN GREENSTONE, BLACK SHALE AND DARK GRAY GRAYWACKE IN A SHEARED SERPENTINE MATRIX<br>CP=1000 PSI - D | | SLICKENSIDE SURFACES | 26 | |
| | 38 | | | | | 28 | |
| 266 | | | | | | 26 | |
| | 36 | | | 30 | | 35 | RUN #23 |
| 268 | | | | | | | |

FR SW MW HW XW
VW W MS S VS

LOG OF BORING

DAMES & MOORE

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 28
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION LINCOLN PARK
ELEV. 303
PAGE 6 OF 8



CLAST SIZE LESS THAN 0.2 INCHES

MODERATELY FRESH GRAYWACKE CLAST

HIGHLY WEATHERED SERPENTINITIC MATRIX MELANGE WITH GREENSTONE SHALE AND GRAYWACKE CLASTS

CONTORTED AND BRECCIATED INTERLAYERED BLACK SHALE MEDIUM GRAY, MEDIUM GRAINED GRAYWACKE
CP=3800 PSI - D

RED-BROWN GREENSTONE CLASTS

SLICKENSIDE SURFACES

MODERATE TO HIGH SUSCEPTIBILITY TO SLAKING

CALCITE VEINING

SLICKENSIDE SURFACES

RUN #23 CONT'D

RUN #24

DP=>100 PSI

RUN #25

DP= 0 PSI

RUN #26

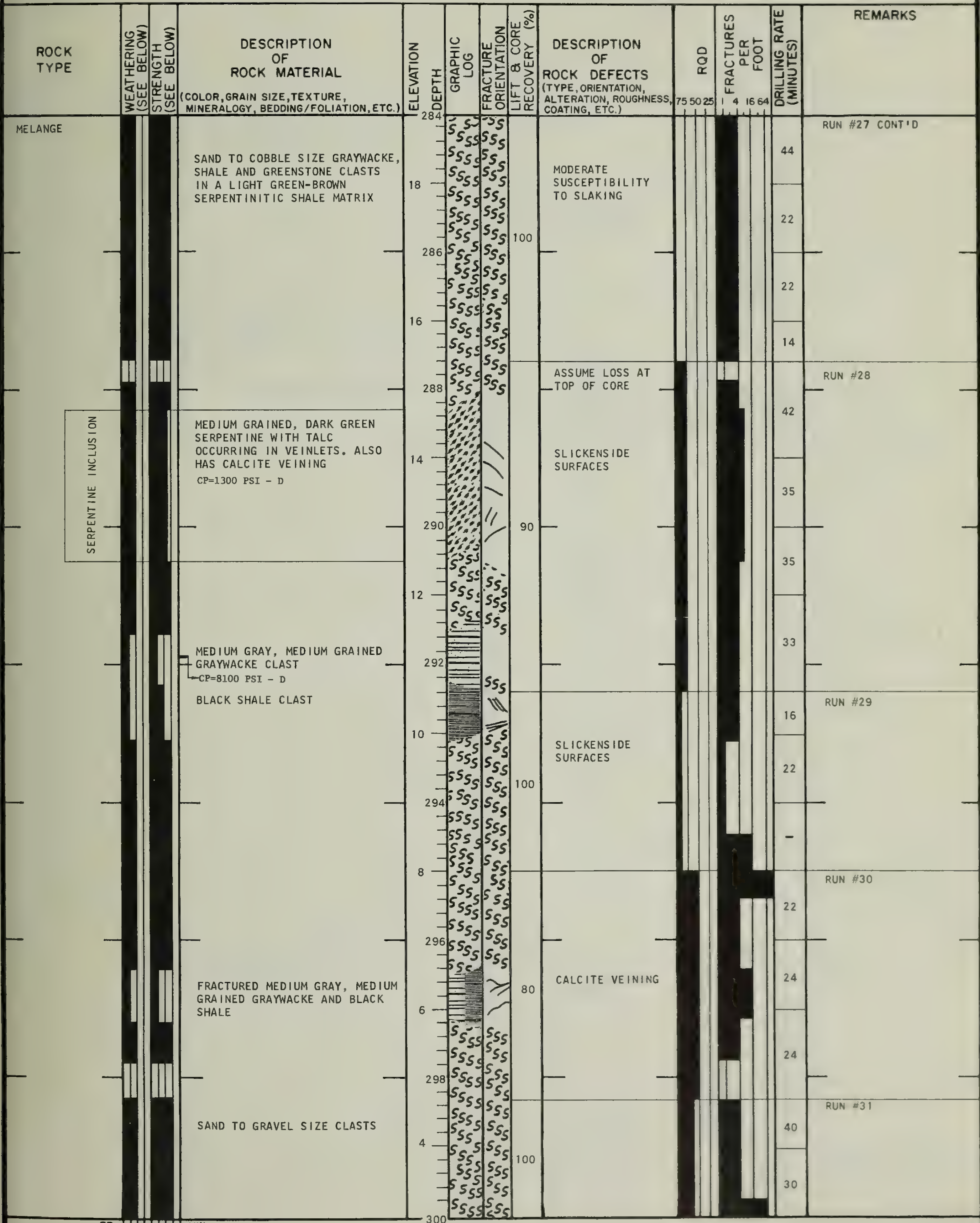
RUN #27

## LOG OF BORING

DAMES & MOORE

PLATE A-1AB/6

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 28
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION LINCOLN PARK
ELEV. 303
PAGE 7 OF 8



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | DEPTH | ELEVATION | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| MELANGE | | 284 | | | | | RUN #27 CONT'D |
| | SAND TO COBBLE SIZE GRAYWACKE, SHALE AND GREENSTONE CLASTS IN A LIGHT GREEN-BROWN SERPENTINITIC SHALE MATRIX | | 18 | | MODERATE SUSCEPTIBILITY TO SLAKING | 44 | |
| | | 286 | | 100 | | 22<br>22 | |
| | | | 16 | | | 14 | |
| | | 288 | | | ASSUME LOSS AT TOP OF CORE | | RUN #28 |
| SERPENTINE INCLUSION | MEDIUM GRAINED, DARK GREEN SERPENTINE WITH TALC OCCURRING IN VEINLETS. ALSO HAS CALCITE VEINING<br>CP=1300 PSI - D | | 14 | | SLICKENSIDE SURFACES | 42<br>35 | |
| | | 290 | | 90 | | 35 | |
| | | | 12 | | | 33 | |
| | MEDIUM GRAY, MEDIUM GRAINED GRAYWACKE CLAST<br>CP=8100 PSI - D | 292 | | | | | |
| | BLACK SHALE CLAST | | | | | | RUN #29 |
| | | | 10 | | SLICKENSIDE SURFACES | 16<br>22 | |
| | | 294 | | 100 | | – | |
| | | | 8 | | | | RUN #30 |
| | | 296 | | | | 22 | |
| | FRACTURED MEDIUM GRAY, MEDIUM GRAINED GRAYWACKE AND BLACK SHALE | | 6 | 80 | CALCITE VEINING | 24 | |
| | | 298 | | | | 24 | RUN #31 |
| | SAND TO GRAVEL SIZE CLASTS | | 4 | 100 | | 40<br>30 | |
| | | 300 | | | | | |

FR
SW
MW
HW
XW

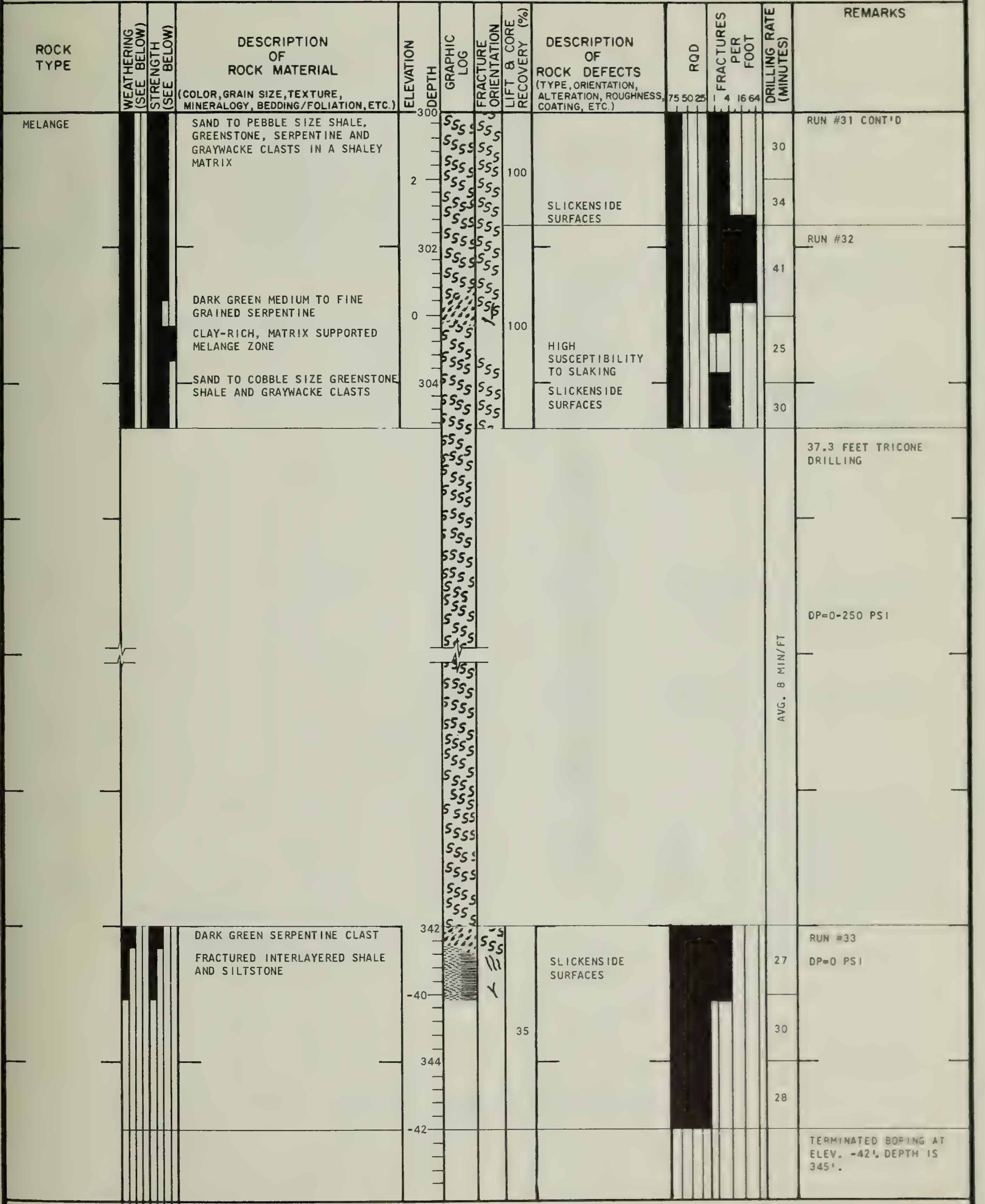
VW
W
MS
S
VS

# LOG OF BORING

DAMES & MOORE

PLATE A-IAB/7

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 28
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION LINCOLN PARK
ELEV. 303
PAGE 8 OF 8



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| MELANGE | SAND TO PEBBLE SIZE SHALE, GREENSTONE, SERPENTINE AND GRAYWACKE CLASTS IN A SHALEY MATRIX | 2 | 300 | 100 | SLICKENSIDE SURFACES | 30<br>34 | RUN #31 CONT'D |
| | DARK GREEN MEDIUM TO FINE GRAINED SERPENTINE<br>CLAY-RICH, MATRIX SUPPORTED MELANGE ZONE<br>SAND TO COBBLE SIZE GREENSTONE SHALE AND GRAYWACKE CLASTS | 0 | 302<br>304 | 100 | HIGH SUSCEPTIBILITY TO SLAKING<br>SLICKENSIDE SURFACES | 41<br>25<br>30 | RUN #32 |
| | | | | | | AVG. 8 MIN/FT | 37.3 FEET TRICONE DRILLING<br>DP=0-250 PSI |
| | DARK GREEN SERPENTINE CLAST<br>FRACTURED INTERLAYERED SHALE AND SILTSTONE | -40 | 342<br>344 | 35 | SLICKENSIDE SURFACES | 27<br>30<br>28 | RUN #33<br>DP=0 PSI |
| | | -42 | | | | | TERMINATED BORING AT ELEV. -42'. DEPTH IS 345'. |

FR
SW
MW
HW
XW

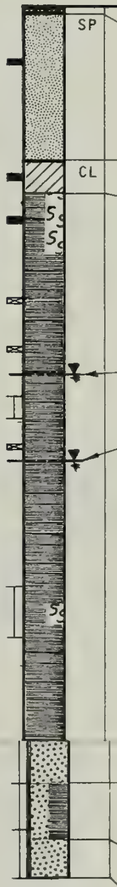
VW
W
MS
S
VS

## LOG OF BORING

**DAMES & MOORE**

## BORING 29
DRILLED 7/12 -26/78

| ELEVATION | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS |  | SHEAR STRENGTH TEST RESULTS |  |  |  |  | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD.PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | LABORATORY |  |  | FIELD |  |  |  |  |  |
|  |  |  |  | LIQUID LIMIT | PLASTIC LIMIT | TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | TORVANE (PSF) | PENETROMETER (PSF) |  |  |  |  |
| +240 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  | U-1 | 100 | 12 |
| +230 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| +220 |  |  |  |  |  |  |  |  |  |  |  | U-1 | 100 | 16 |
|  |  |  |  |  |  |  |  |  |  |  |  | U-1 | 83 | 40/6" |
| +210 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  | GRAB |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  | GRAB |  |  |
| +200 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  | 5<br>5<br>5 | PT |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  | GRAB |  |  |
| +190 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| +180 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  | 9<br>9<br>3<br>6<br>6 | NX | 90 |  |
| +170 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  | 5 |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  | 10<br>11<br>12<br>8 | NX | 100 |  |
| 0 |  |  |  |  |  |  |  |  |  |  | 10<br>9<br>9<br>9<br>9 | NX | 100 |  |
|  |  |  |  |  |  |  |  |  |  |  | 10<br>10<br>11<br>7 | NX | 100 |  |
| -10 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |



ELEVATION +238'

ASPHALTIC CONCRETE OVER 6" CONCRETE

BROWN FINE SAND (DUNE SAND)

(GRADING MEDIUM DENSE)

REDDISH BROWN SANDY CLAY (STIFF)
(GRADING YELLOW-REDDISH BROWN MOTTLED)

GRAY-BROWN SHALE (GREAT VALLEY BEDROCK)
HIGHLY WEATHERED, SHEARED, WEAK TO VERY WEAK.
(GRADING HARDER)

(GRADING HARDER)

(WATER LEVEL, 11/15/78)

(WATER LEVEL, 8/2/78)

(HIGHLY WEAHTERED SANDSTONE INTERBED)

(OCCASIONAL THIN SANDSTONE INTERBEDS)

(SHEAR ZONE, HIGHLY WEATHERED, VERY WEAK)

DARK GRAY MEDIUM GRAINED SANDSTONE AND BLACK SHALE IN SPORADIC CONTORTED INTERBEDS. FRESH, STRONG RQD = 75. FRACTURES ARE CLEAN AND ROUGH.

MEDIUM TO DARK GRAY MEDIUM GRAINED SANDSTONE. MASSIVE, FRESH, VERY STRONG, MANY CALCITE VEINLETS.

NOTES:

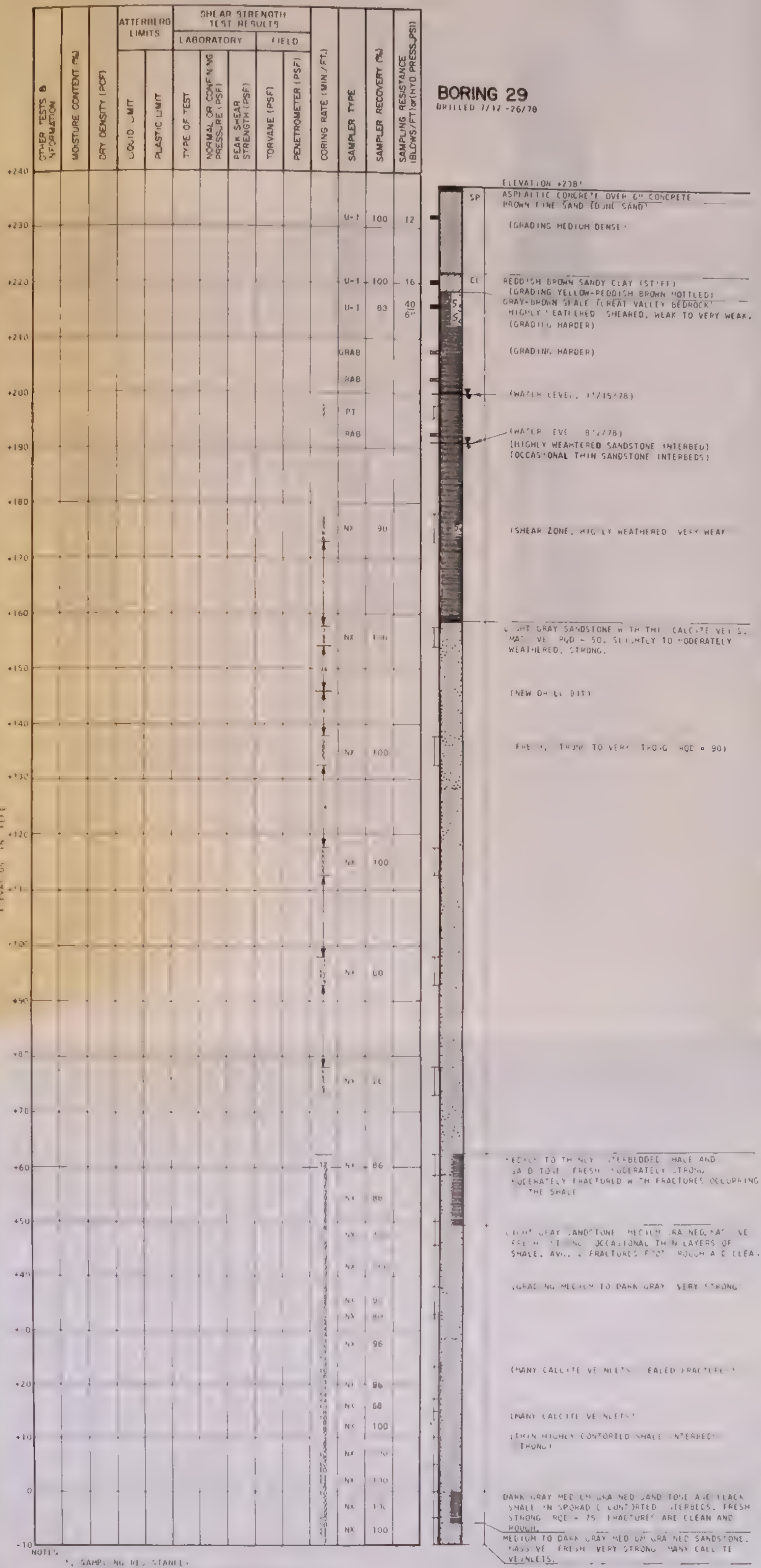
1. SAMPLING RESISTANCE:
   U DRIVEN WITH 275# SLIPJARS FALLING 30"
2. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED ON OFFICIAL CITY GRADE.
3. REFER TO FOLLOWING GEOLOGIC LOGS FOR A MORE DETAILED DESCRIPTION OF THE BEDROCK.

# LOG OF BORING

**DAMES & MOORE**

PLATE A-IAC

## BORING 29
DRILLED 7/12 -26/78



ELEVATION +238'
ASPHALTIC CONCRETE OVER 6" CONCRETE
BROWN FINE SAND (DUNE SAND)
(GRADING MEDIUM DENSE)

REDDISH BROWN SANDY CLAY (STIFF)
(GRADING YELLOW-REDDISH BROWN MOTTLED)
GRAY-BROWN SHALE (GREAT VALLEY BEDROCK)
HIGHLY WEATHERED, SHEARED, WEAK TO VERY WEAK.
(GRADING HARDER)

(GRADING HARDER)

(WATER LEVEL, 11/15/78)

(WATER LEVEL 8/2/78)
(HIGHLY WEAHTERED SANDSTONE INTERBED)
(OCCASIONAL THIN SANDSTONE INTERBEDS)

(SHEAR ZONE, HIGHLY WEATHERED, VERY WEAK

LIGHT GRAY SANDSTONE WITH THIN CALCITE VEINS.
MASSIVE. RQD = 50. SLIGHTLY TO MODERATELY
WEATHERED, STRONG.

(NEW DRILL BIT)

(FRESH, STRONG TO VERY STRONG RQD = 90)

MEDIUM TO THINLY INTERBEDDED SHALE AND
SANDSTONE, FRESH, MODERATELY STRONG,
MODERATELY FRACTURED WITH FRACTURES OCCURRING
IN THE SHALE

LIGHT GRAY SANDSTONE, MEDIUM GRAINED, MASSIVE,
FRESH, STRONG, OCCASIONAL THIN LAYERS OF
SHALE. [illegible] FRACTURES [illegible] ROUGH AND CLEAN.

(GRADING MEDIUM TO DARK GRAY, VERY STRONG)

(MANY CALCITE VEINLETS, HEALED FRACTURES)

(MANY CALCITE VEINLETS)

(THIN HIGHLY CONTORTED SHALE INTERBEDS
STRONG)

DARK GRAY MEDIUM GRAINED SANDSTONE AND BLACK
SHALE IN SPORADIC CONTORTED INTERBEDS. FRESH
STRONG. RQD = 75. FRACTURES ARE CLEAN AND
ROUGH.
MEDIUM TO DARK GRAY MEDIUM GRAINED SANDSTONE.
MASSIVE, FRESH, VERY STRONG, MANY CALCITE
VEINLETS.

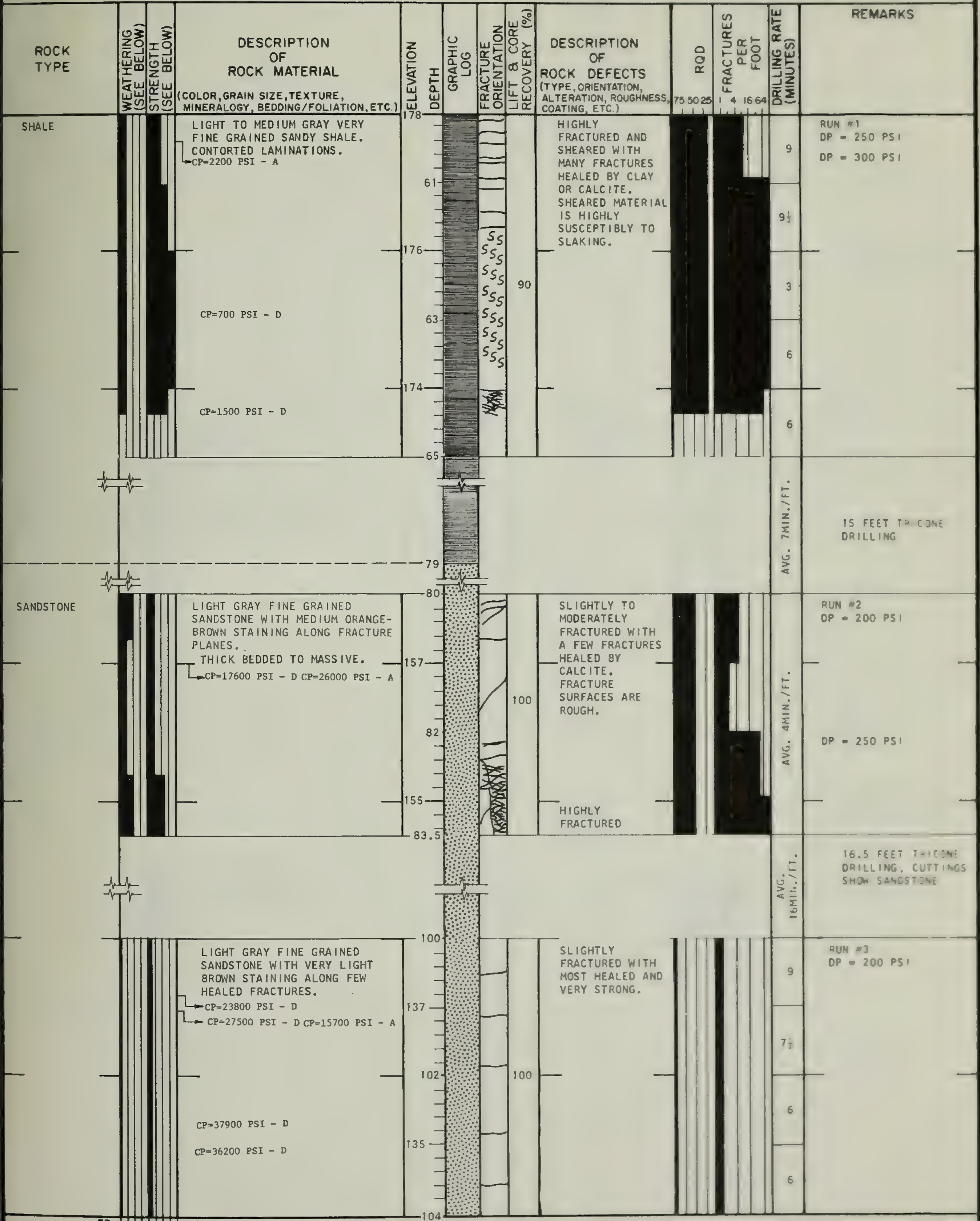
NOTES:
1. SAMPLING RESISTANCE:
* DRIVEN WITH [illegible] FALLING 30
2. ELEVATIONS REFER TO [illegible] DATUM AND ARE BASED
ON [illegible]
3. REFER TO FOLLOWING GEOLOGIC LOGS FOR A MORE
DETAILED DESCRIPTION OF THE BEDROCK

# LOG OF BORING

**DAMES & MOORE**

PLATE A-IAC

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
PROJECT: RICHMOND TRANSPORT SEWER
DRILLING METHOD: ROTARY WASH - NX CORING WITH REVERT SLURRY
LOCATION: 46th. AVE. AT GEARY, S.F.
ELEV. 238
BORING NO. 29
ANGLE FROM HORIZONTAL 90°
PAGE 1 OF 8



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| SHALE | LIGHT TO MEDIUM GRAY VERY FINE GRAINED SANDY SHALE. CONTORTED LAMINATIONS.<br>CP=2200 PSI - A<br>CP=700 PSI - D<br>CP=1500 PSI - D | 178<br>176<br>174 | 61<br>63<br>65 | 90 | HIGHLY FRACTURED AND SHEARED WITH MANY FRACTURES HEALED BY CLAY OR CALCITE. SHEARED MATERIAL IS HIGHLY SUSCEPTIBLY TO SLAKING. | 9<br>9½<br>3<br>6<br>6 | RUN #1<br>DP = 250 PSI<br>DP = 300 PSI |
| | | | 79 | | | AVG. 7MIN./FT. | 15 FEET TRICONE DRILLING |
| SANDSTONE | LIGHT GRAY FINE GRAINED SANDSTONE WITH MEDIUM ORANGE-BROWN STAINING ALONG FRACTURE PLANES.<br>THICK BEDDED TO MASSIVE.<br>CP=17600 PSI - D CP=26000 PSI - A | 157<br>155 | 80<br>82<br>83.5 | 100 | SLIGHTLY TO MODERATELY FRACTURED WITH A FEW FRACTURES HEALED BY CALCITE. FRACTURE SURFACES ARE ROUGH.<br>HIGHLY FRACTURED | AVG. 4MIN./FT. | RUN #2<br>DP = 200 PSI<br>DP = 250 PSI |
| | | | | | | AVG. 16MIN./FT. | 16.5 FEET TRICONE DRILLING, CUTTINGS SHOW SANDSTONE |
| | LIGHT GRAY FINE GRAINED SANDSTONE WITH VERY LIGHT BROWN STAINING ALONG FEW HEALED FRACTURES.<br>CP=23800 PSI - D<br>CP=27500 PSI - D CP=15700 PSI - A<br>CP=37900 PSI - D<br>CP=36200 PSI - D | 137<br>135 | 100<br>102<br>104 | 100 | SLIGHTLY FRACTURED WITH MOST HEALED AND VERY STRONG. | 9<br>7½<br>6<br>6 | RUN #3<br>DP = 200 PSI |

FR
SW
MW
HW
XW

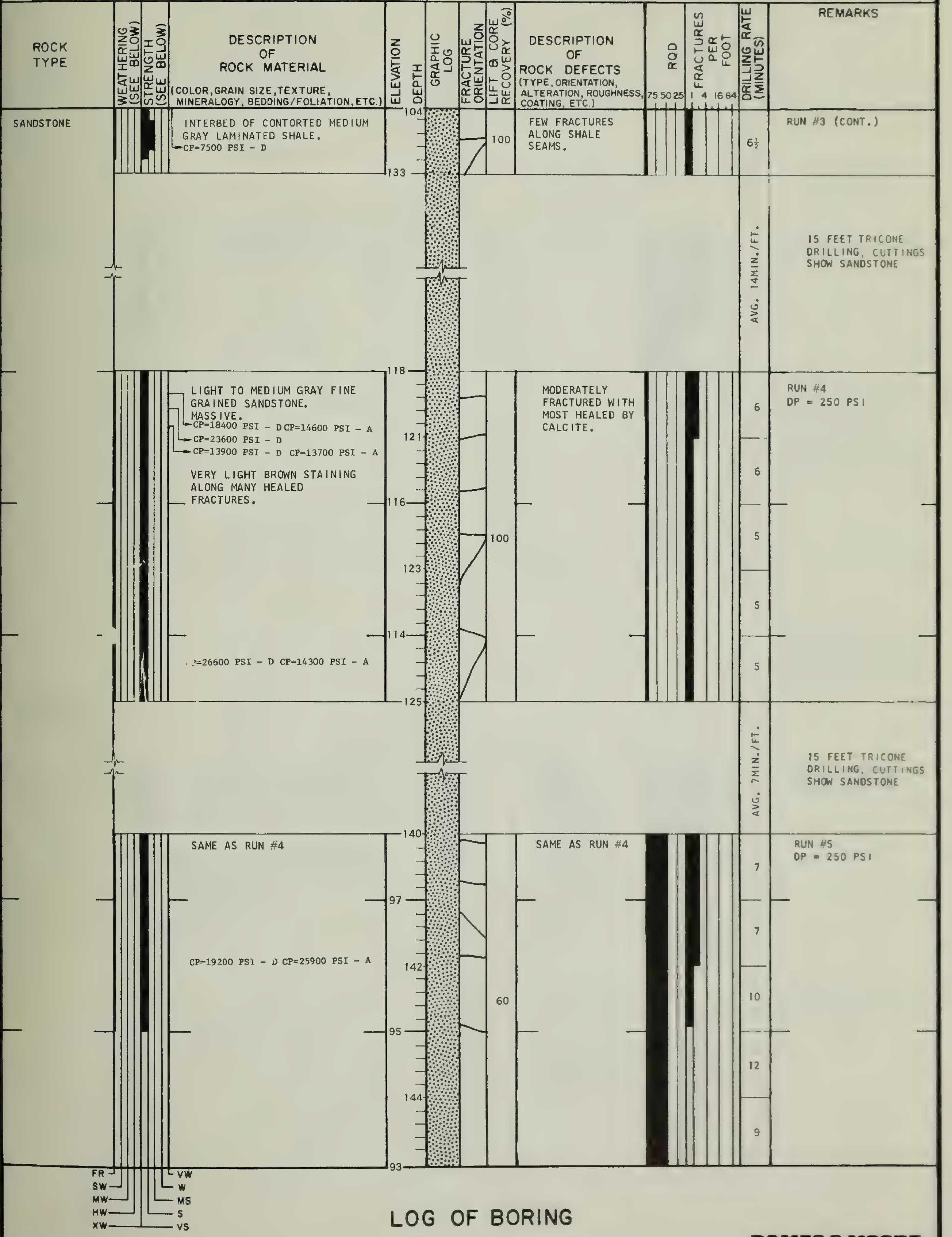
VW
W
MS
S
VS

# LOG OF BORING

**DAMES & MOORE**

PLATE A-IAC/1

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 29
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH-NX CORING WITH REVERT SLURRY
LOCATION 46th. AVE. AT GEARY, S.F.
ELEV. 238
PAGE 2 OF 8



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|
| SANDSTONE | INTERBED OF CONTORTED MEDIUM GRAY LAMINATED SHALE.<br>CP=7500 PSI - D | 100 | FEW FRACTURES ALONG SHALE SEAMS. | 6½ | RUN #3 (CONT.) |
| | | | | AVG. 14MIN./FT. | 15 FEET TRICONE DRILLING, CUTTINGS SHOW SANDSTONE |
| | LIGHT TO MEDIUM GRAY FINE GRAINED SANDSTONE. MASSIVE.<br>CP=18400 PSI - D CP=14600 PSI - A<br>CP=23600 PSI - D<br>CP=13900 PSI - D CP=13700 PSI - A<br>VERY LIGHT BROWN STAINING ALONG MANY HEALED FRACTURES.<br>P=26600 PSI - D CP=14300 PSI - A | 100 | MODERATELY FRACTURED WITH MOST HEALED BY CALCITE. | 6<br>6<br>5<br>5<br>5 | RUN #4<br>DP = 250 PSI |
| | | | | AVG. 7MIN./FT. | 15 FEET TRICONE DRILLING, CUTTINGS SHOW SANDSTONE |
| | SAME AS RUN #4<br>CP=19200 PSI - D CP=25900 PSI - A | 60 | SAME AS RUN #4 | 7<br>7<br>10<br>12<br>9 | RUN #5<br>DP = 250 PSI |

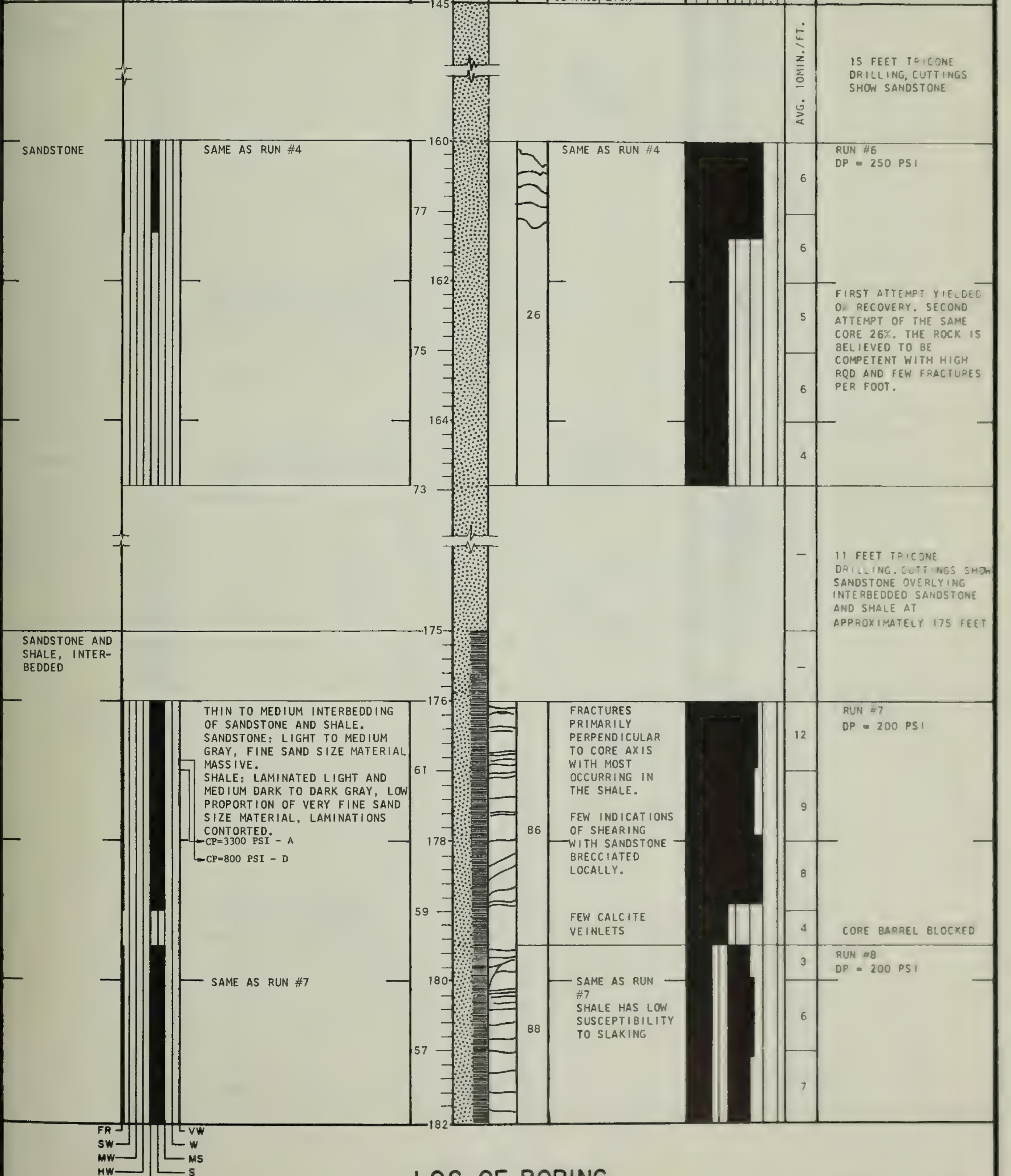
LOG OF BORING

**DAMES & MOORE**

PLATE A-1AC/2

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 29
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH - NX CORING WITH REVERT SLURRY
LOCATION 46th. AVE. AT GEARY, S.F.
ELEV. 238
PAGE 3 OF 8

| ROCK TYPE | WEATHERING (SEE BELOW) | STRENGTH (SEE BELOW) | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | GRAPHIC LOG | FRACTURE ORIENTATION | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | RQD 75 50 25 | FRACTURES PER FOOT 1 4 16 64 | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 145–160 | | | | | | | AVG. 10MIN./FT. | 15 FEET TRICONE DRILLING, CUTTINGS SHOW SANDSTONE |
| SANDSTONE | | | SAME AS RUN #4 | 77, 75, 73 | 160–165 | | | 26 | SAME AS RUN #4 | | | 6<br>6<br>5<br>6<br>4 | RUN #6<br>DP = 250 PSI<br>FIRST ATTEMPT YIELDED 0% RECOVERY. SECOND ATTEMPT OF THE SAME CORE 26%. THE ROCK IS BELIEVED TO BE COMPETENT WITH HIGH RQD AND FEW FRACTURES PER FOOT. |
| | | | | | 165–176 | | | | | | | –<br>– | 11 FEET TRICONE DRILLING. CUTTINGS SHOW SANDSTONE OVERLYING INTERBEDDED SANDSTONE AND SHALE AT APPROXIMATELY 175 FEET |
| SANDSTONE AND SHALE, INTERBEDDED | | | THIN TO MEDIUM INTERBEDDING OF SANDSTONE AND SHALE. SANDSTONE: LIGHT TO MEDIUM GRAY, FINE SAND SIZE MATERIAL MASSIVE. SHALE: LAMINATED LIGHT AND MEDIUM DARK TO DARK GRAY, LOW PROPORTION OF VERY FINE SAND SIZE MATERIAL, LAMINATIONS CONTORTED.<br>CP=3300 PSI - A<br>CP=800 PSI - D | 61, 59 | 176–179.5 | | | 86 | FRACTURES PRIMARILY PERPENDICULAR TO CORE AXIS WITH MOST OCCURRING IN THE SHALE.<br>FEW INDICATIONS OF SHEARING WITH SANDSTONE BRECCIATED LOCALLY.<br>FEW CALCITE VEINLETS | | | 12<br>9<br>8<br>4 | RUN #7<br>DP = 200 PSI<br>CORE BARREL BLOCKED |
| | | | SAME AS RUN #7 | 57 | 179.5–182 | | | 88 | SAME AS RUN #7<br>SHALE HAS LOW SUSCEPTIBILITY TO SLAKING | | | 3<br>6<br>7 | RUN #8<br>DP = 200 PSI |



LOG OF BORING

DAMES & MOORE

PLATE A-IAC/3

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)

BORING NO. 29

PROJECT: RICHMOND TRANSPORT SEWER

ANGLE FROM HORIZONTAL 90°

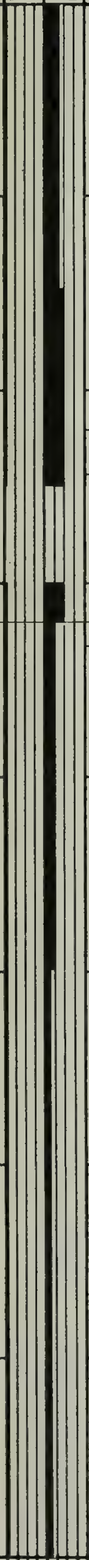
DRILLING METHOD: ROTARY WASH-NX CORING WITH REVERT SLURRY

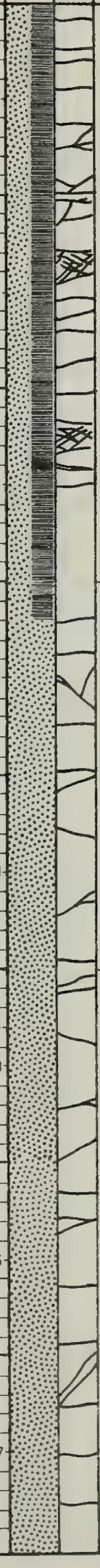
LOCATION 46th. AVE. AT GEARY, S.F.

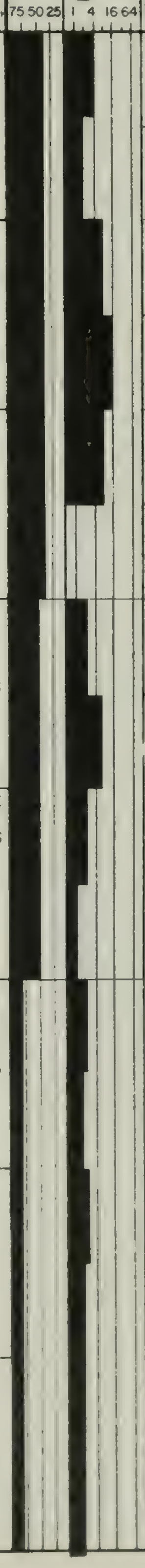
ELEV. 238

PAGE 4 OF 8

| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| SANDSTONE AND SHALE, INTERBEDDED | CP=17500 PSI - D CP=10800 PSI - A | 56 | | | SAME AS RUN #7 | 9 | RUN #8 (CONT.)<br>DP = 200 PSI |
| | | | 183 | | FRACTURES ARE ROUGH. SHALE HAS LOW SUSCEPTIBILITY TO SLAKING. | 8 | |
| | | 54 | | | | 8 | |
| | | | 185 | 88 | | 7 | |
| | LOWEST 2 FEET RECOVERED CONSISTS PRIMARILY OF SANDSTONE WITH FEW ANGULAR NODULES OF DARK GRAY SHALE.<br>CP=6100 PSI - D | 52 | | | | 8 | |
| | CP=4600 PSI - A | | 187 | | | 8 | |
| SANDSTONE | LIGHT TO MEDIUM GRAY, FINE TO MEDIUM GRAINED SANDSTONE. MASSIVE<br>CP=14700 PSI - D | 50 | | | MODERATELY FRACTURED WITH SURFACES COMMONLY ROUGH. CALCITE VEINLETS ABUNDANT. | 8 | RUN #9<br>DP = 275 PSI |
| | | | 189 | | | 11 | |
| | | 48 | | 100 | THIN BLACK SHALE BED AT 191 FEET, 45° TO CORE AXIS LOW SUSCEPTIBILITY TO SLAKING. | 10 | |
| | CP=19500 PSI - D | | 191 | | | 9 | |
| | SAME AS RUN #9<br>CP=20700 PSI - D | 46 | | | MODERATELY FRACTURED WITH SURFACES COMMONLY COATED WITH IRON OXIDE, ROUGH. CALCITE VEINLETS ABUNDANT. | 11 | RUN #10<br>DP = 200 PSI |
| | | | 193 | | | 9 | |
| | | 44 | | | | 7 | |
| | FEW, VERY THIN, CONTORTED LAYERS OF DARK GRAY SHALE<br>CP=20700 PSI - D CP=25400 PSI - A | | 195 | 100 | | 9 | |
| | | 42 | | | | 9 | |
| | CP=28000 PSI - D CP=32700 PSI - A | | 197 | | | 11 | |
| | | 40 | | | | | |







FR — SW — MW — HW — XW

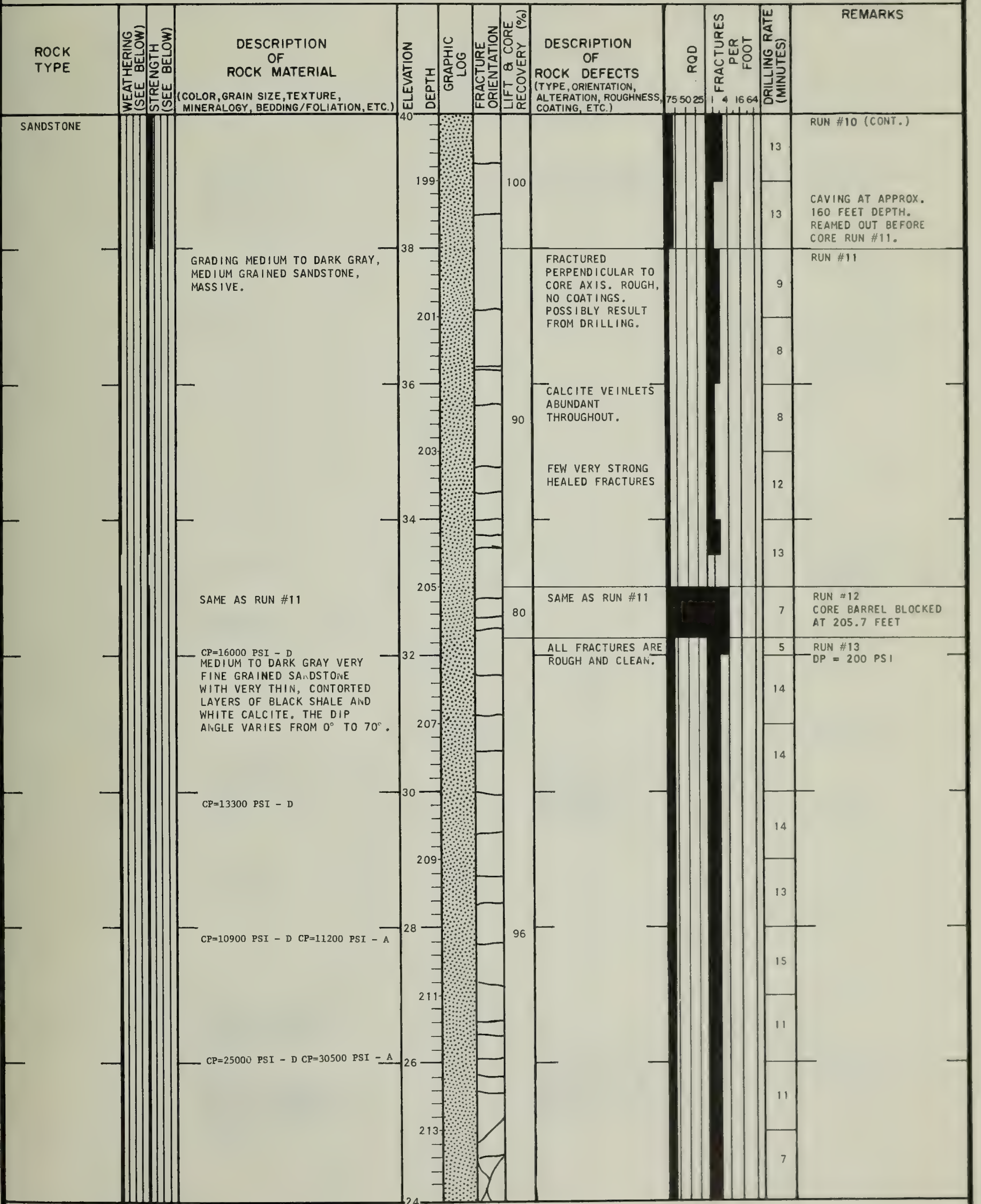
VW — W — MS — S — VS

LOG OF BORING

**DAMES & MOORE**

PLATE A-1AC/4

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 29
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH-NX CORING WITH REVERT SLURRY
LOCATION 46th. AVE. AT GEARY, S.F.
ELEV. 238
PAGE 5 OF 8



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| SANDSTONE | | 40 | | | | 13 | RUN #10 (CONT.) |
| | | | 199 | 100 | | 13 | CAVING AT APPROX. 160 FEET DEPTH. REAMED OUT BEFORE CORE RUN #11. |
| | GRADING MEDIUM TO DARK GRAY, MEDIUM GRAINED SANDSTONE, MASSIVE. | 38 | | | FRACTURED PERPENDICULAR TO CORE AXIS. ROUGH, NO COATINGS. POSSIBLY RESULT FROM DRILLING. | 9 | RUN #11 |
| | | | 201 | | | 8 | |
| | | 36 | | 90 | CALCITE VEINLETS ABUNDANT THROUGHOUT. | 8 | |
| | | | 203 | | FEW VERY STRONG HEALED FRACTURES | 12 | |
| | | 34 | | | | 13 | |
| | SAME AS RUN #11 | | 205 | 80 | SAME AS RUN #11 | 7 | RUN #12<br>CORE BARREL BLOCKED AT 205.7 FEET |
| | | | | | ALL FRACTURES ARE ROUGH AND CLEAN. | 5 | RUN #13<br>DP = 200 PSI |
| | CP=16000 PSI - D<br>MEDIUM TO DARK GRAY VERY FINE GRAINED SANDSTONE WITH VERY THIN, CONTORTED LAYERS OF BLACK SHALE AND WHITE CALCITE. THE DIP ANGLE VARIES FROM 0° TO 70°. | 32 | | | | 14 | |
| | | | 207 | | | 14 | |
| | CP=13300 PSI - D | 30 | | | | 14 | |
| | | | 209 | | | 13 | |
| | CP=10900 PSI - D CP=11200 PSI - A | 28 | | 96 | | 15 | |
| | | | 211 | | | 11 | |
| | CP=25000 PSI - D CP=30500 PSI - A | 26 | | | | 11 | |
| | | | 213 | | | 7 | |
| | | 24 | | | | | |

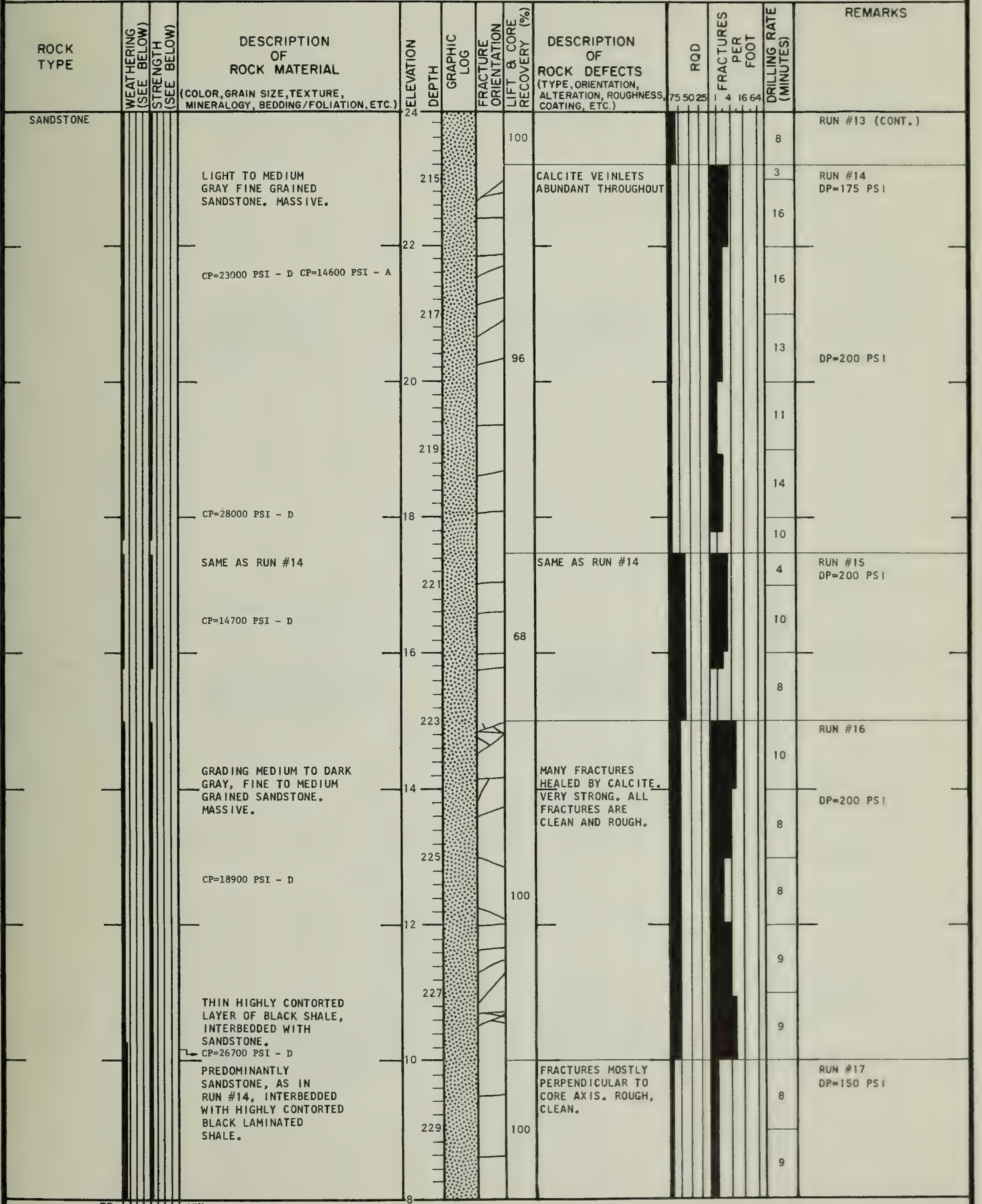
FR SW MW HW XW
VW W MS S VS

# LOG OF BORING

DAMES & MOORE

PLATE A-IAC/5

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 29
PROJECT: RICHMOND TRANSPORT SEWER
DRILLING METHOD: ROTARY WASH-NX CORING WITH REVERT SLURRY
ANGLE FROM HORIZONTAL 90°
LOCATION 46th. AVE. AT GEARY, S.F.
ELEV. 238
PAGE 6 OF 8



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ROUGHNESS, ALTERATION, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|
| SANDSTONE | | 100 | | 8 | RUN #13 (CONT.) |
| | LIGHT TO MEDIUM GRAY FINE GRAINED SANDSTONE. MASSIVE.<br>CP=23000 PSI - D CP=14600 PSI - A<br>CP=28000 PSI - D | 96 | CALCITE VEINLETS ABUNDANT THROUGHOUT | 3<br>16<br>16<br>13<br>11<br>14<br>10 | RUN #14<br>DP=175 PSI<br>DP=200 PSI |
| | SAME AS RUN #14<br>CP=14700 PSI - D | 68 | SAME AS RUN #14 | 4<br>10<br>8 | RUN #15<br>DP=200 PSI |
| | GRADING MEDIUM TO DARK GRAY, FINE TO MEDIUM GRAINED SANDSTONE. MASSIVE.<br>CP=18900 PSI - D<br>THIN HIGHLY CONTORTED LAYER OF BLACK SHALE, INTERBEDDED WITH SANDSTONE.<br>CP=26700 PSI - D | 100 | MANY FRACTURES HEALED BY CALCITE. VERY STRONG. ALL FRACTURES ARE CLEAN AND ROUGH. | 10<br>8<br>8<br>9<br>9 | RUN #16<br>DP=200 PSI |
| | PREDOMINANTLY SANDSTONE, AS IN RUN #14, INTERBEDDED WITH HIGHLY CONTORTED BLACK LAMINATED SHALE. | 100 | FRACTURES MOSTLY PERPENDICULAR TO CORE AXIS. ROUGH, CLEAN. | 8<br>9 | RUN #17<br>DP=150 PSI |

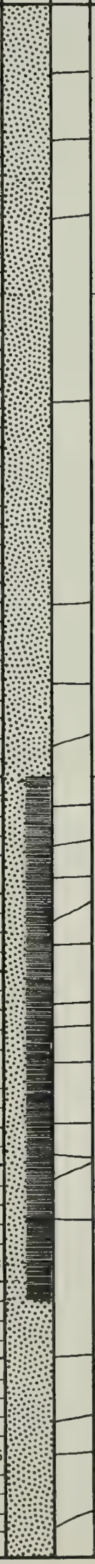
LOG OF BORING

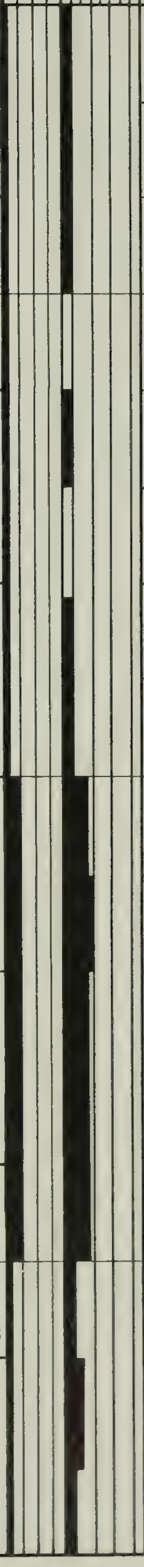
DAMES & MOORE

PLATE A-1AC/6

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 29
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH-NX CORING WITH REVERT SLURRY
LOCATION 46th. AVE. AT GEARY, S.F.
ELEV. 238
PAGE 7 OF 8

| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| SANDSTONE | CP=84200 PSI - D | 8 | | | | 10 | RUN #17 (CONT.) |
| | | | 231 | 100 | | 9 | |
| | CP=15300 PSI - D | 6 | | | | 8 | |
| | DARK GRAY MEDIUM GRAINED SANDSTONE THICK BEDDED TO MASSIVE | | 233 | | AN ABUNDANCE OF FRACTURES HEALED BY CALCITE. VERY STRONG. | 10 | RUN #18<br>DP=200 PSI |
| | CP=39200 PSI - D | 4 | | | | 10 | |
| | | | 235 | 100 | | 11 | |
| | CP=17600 PSI - D | 2 | | | | 12 | |
| | FEW, HIGHLY CONTORTED, BLACK SHALE INTERBEDS | | 237 | | | 8 | |
| SANDSTONE AND SHALE INTERBEDDED | INTERBEDDED DARK GRAY MEDIUM GRAINED SANDSTONE AND BLACK SANDY SHALE. INTERBEDS ARE SPORADIC AND HIGHLY CONTORTED. | 0 | | | AN ABUNDANCE OF CALCITE VEINLETS FRACTURES ARE CLEAN AND ROUGH | 10 | RUN #19<br>DP=200 PSI |
| | CP=18400 PSI - D | | 239 | | | 9 | |
| | | -2 | | 100 | | 9 | |
| | | | 241 | | | 9 | DP=150 PSI |
| | | -4 | | | | 9 | |
| SANDSTONE | MEDIUM TO DARK GRAY MEDIUM GRAINED SANDSTONE. MASSIVE. | | 243 | | MODERATE ABUNDANCE OF CALCITE VEINLETS | 10 | RUN #20<br>DP=150 PSI |
| | CP=35900 PSI - D CP=19600 PSI - A | -6 | | 100 | | 10 | |
| | | | 245 | | | 11 | |
| | | -8 | | | | | |





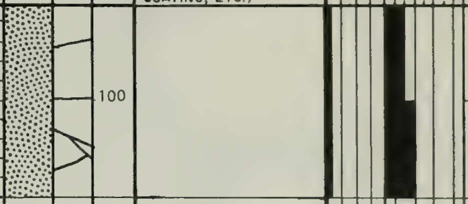
WEATHERING (SEE BELOW): FR, SW, MW, HW, XW
STRENGTH (SEE BELOW): VW, W, MS, S, VS

# LOG OF BORING

DAMES & MOORE

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 29
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH-NX CORING WITH REVERT SLURRY
LOCATION 46th. AVE. AT GEARY, S.F.
ELEV. 238
PAGE 8 OF 8

| ROCK TYPE | WEATHERING (SEE BELOW) | STRENGTH (SEE BELOW) | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | GRAPHIC LOG | FRACTURE ORIENTATION | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | RQD 75 50 25 | FRACTURES PER FOOT 1 4 16 64 | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SANDSTONE | | | | -8 | 247 | | | 100 | | | | 11<br>7 | RUN #20 (CONT.)<br>DP=200 PSI |
| | | | | -10 | | | | | | | | | TERMINATION OF BORING AT ELEV. -10 FEET. DEPTH IS 248 FEET. |



FR, SW, MW, HW, XW
VW, W, MS, S, VS

LOG OF BORING

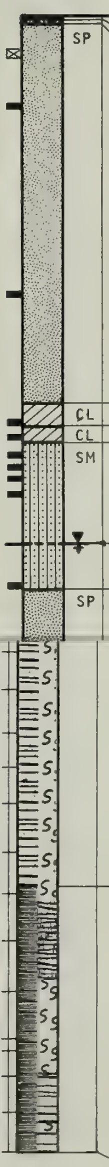
**DAMES & MOORE**

PLATE A-IAC/8

## BORING 30
DRILLED 8/3-17/78

+320 +310 +300 +290 +280 +270 +260 … +40 +30 +20 +10 0 -10

| OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | SHEAR STRENGTH TEST RESULTS, LABORATORY: TYPE OF TEST | LABORATORY: NORMAL OR CONFINING PRESSURE (PSF) | LABORATORY: PEAK SHEAR STRENGTH (PSF) | FIELD: TORVANE (PSF) | FIELD: PENETROMETER (PSF) | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT) or (HYD. PRESS., PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | GRAB | | |
| | | | | | | | | | | | U-1 | 67 | 26 |
| | | | | | | | | | | | U-1 | 83 | 35 |
| | | | | | | | | | | | U-1 | 100 | 55 |
| | | | | | | | | | | | U-1 | 100 | 26 |
| | | | | | | | | | | | U-1 | 83 | 29 |
| | | | | | | | | | | | U-1 | 83 | 36 |
| | | | | | | | | | | | U-1 | 100 | 55 |
| | | | | | | | | | | | U-1 | 100 | 23 |
| | | | | | | | | | | | U-1 | 100 | 59 |
| | | | | | | | | | | 33 | NX | 100 | |
| | | | | | | | | | | 10<br>17<br>15<br>22<br>10 | NX | 50 | |
| | | | | | | | | | | 12<br>10<br>10<br>11 | NX | 50 | |
| | | | | | | | | | | 15<br>16<br>18 | NX | 70 | |
| | | | | | | | | | | 23<br>10<br>24 | NX | 50 | |
| | | | | | | | | | | 20<br>18<br>23<br>22<br>24 | NX | 60 | |
| | | | | | | | | | | 15<br>17<br>19<br>19 | NX | 100 | |
| | | | | | | | | | | 15<br>27<br>17<br>19<br>8 | NX | 40 | |
| | | | | | | | | | | 19<br>17<br>21<br>21<br>15 | NX | 20 | |
| | | | | | | | | | | 23<br>21<br>22<br>23<br>10 | NX | 100 | |
| | | | | | | | | | | 15 | NX | 100 | |
| | | | | | | | | | | 17<br>21<br>14 | NX | 60 | |
| | | | | | | | | | | 21<br>19<br>18 | NX | 50 | |
| | | | | | | | | | | 23<br>24<br>24<br>27 | NX | 50 | |



ELEVATION +316'

ASPHALTIC CONCRETE

CONCRETE

SP BROWN FINE SAND (DUNE SAND)

(MEDIUM DENSE)

(GRADING DENSE)

CL BLACK SANDY SILTY CLAY (VERY STIFF)

CL GRAY AND BROWN SANDY CLAY (VERY STIFF)

SM GRAY AND BROWN SILTY FINE SAND WITH OCCASIONAL CLAYEY SAND (MEDIUM DENSE TO DENSE)(COLMA FORMATION)

(WATER LEVEL, 10/9/78, 11/15/78)
(GRADING ORANGE-BROWN, DENSE)

SP GRAY-BROWN FINE SAND (VERY DENSE)

BLACK SHEARD SHALE (MELANGE) WITH CONTORTED BEDDING, SLICKENSIDED, SLIGHTLY WEATHERED, WEAK.
(RED AND GREEN GREENSTONE INCLUSION, BRECCIATED, SLIGHTLY WEATHERED, STRONG)

(HIGH SUSCEPTIBILITY TO SLAKING)

(GRAY GRAYWACKE INCLUSION, HIGHLY FRACTURED, SLIGHTLY WEATHERED, STRONG)

(GRAYWACKE INCLUSION, SLIGHTLY WEATHERED, STRONG)

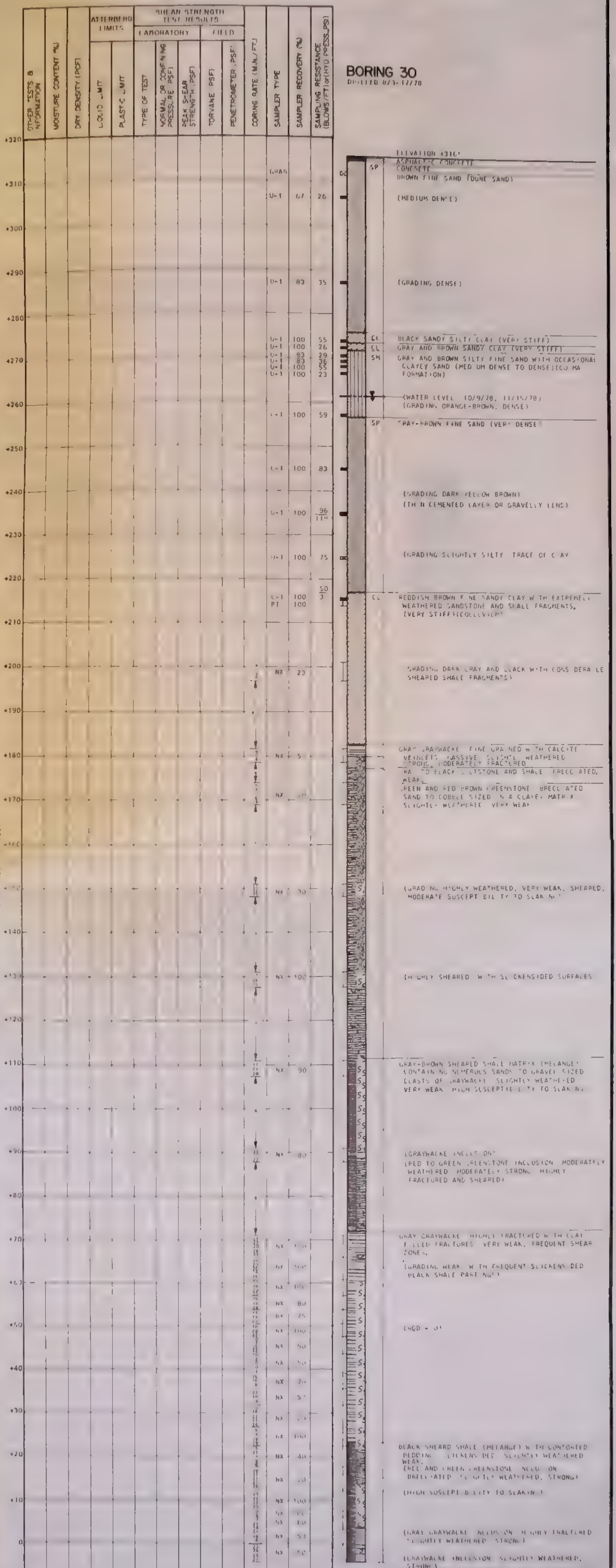
NOTES:
1. SAMPLING RESISTANCE:
   U DRIVEN WITH 240# SLIPJARS FALLING 18"
2. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED ON OFFICIAL CITY GRADE.
3. SEE FOLLOWING GEOLOGIC LOGS FOR A MORE DETAILED DESCRIPTION OF THE BEDROCK

# LOG OF BORING

**DAMES & MOORE**

## BORING 30

DRILLED 8/3-17/78



ELEVATION +316'

ASPHALTIC CONCRETE

CONCRETE

BROWN FINE SAND (DUNE SAND)

(MEDIUM DENSE)

(GRADING DENSE)

BLACK SANDY SILTY CLAY (VERY STIFF)

GRAY AND BROWN SANDY CLAY (VERY STIFF)

GRAY AND BROWN SILTY FINE SAND WITH OCCASIONAL CLAYEY SAND (MEDIUM DENSE TO DENSE)(COLMA FORMATION)

(WATER LEVEL 10/9/78, 11/15/78)

(GRADING ORANGE-BROWN, DENSE)

GRAY-BROWN FINE SAND (VERY DENSE)

(GRADING DARK YELLOW BROWN)

(THIN CEMENTED LAYER OR GRAVELLY LENS)

(GRADING SLIGHTLY SILTY TRACE OF CLAY

REDDISH BROWN FINE SANDY CLAY WITH EXTREMELY WEATHERED SANDSTONE AND SHALE FRAGMENTS. (VERY STIFF)(COLLUVIUM)

(GRADING DARK GRAY AND BLACK WITH CONSIDERABLE SHEARED SHALE FRAGMENTS)

GRAY GRAYWACKE FINE GRAINED WITH CALCITE VEINLETS MASSIVE SLIGHTLY WEATHERED STRONG, MODERATELY FRACTURED

GRAY TO BLACK SILTSTONE AND SHALE BRECCIATED, WEAK.

GREEN AND RED BROWN GREENSTONE BRECCIATED SAND TO COBBLE SIZED IN A CLAYEY MATRIX SLIGHTLY WEATHERED VERY WEAK

(GRADING HIGHLY WEATHERED, VERY WEAK, SHEARED, MODERATE SUSCEPTIBILITY TO SLAKING)

(HIGHLY SHEARED WITH SLICKENSIDED SURFACES

GRAY-BROWN SHEARED SHALE MATRIX (MELANGE) CONTAINING NUMEROUS SANDS TO GRAVEL SIZED CLASTS OF GRAYWACKE SLIGHTLY WEATHERED VERY WEAK HIGH SUSCEPTIBILITY TO SLAKING)

(GRAYWACKE INCLUSION)

(RED TO GREEN GREENSTONE INCLUSION MODERATELY WEATHERED MODERATELY STRONG HIGHLY FRACTURED AND SHEARED)

GRAY GRAYWACKE HIGHLY FRACTURED WITH CLAY FILLED FRACTURES VERY WEAK, FREQUENT SHEAR ZONES.

(GRADING WEAK WITH FREQUENT SLICKENSIDED BLACK SHALE PARTINGS)

(RQD = 0)

BLACK SHEARD SHALE (MELANGE) WITH CONTORTED BEDDING SLICKENSIDED SLIGHTLY WEATHERED WEAK.

(RED AND GREEN GREENSTONE INCLUSION BRECCIATED SLIGHTLY WEATHERED, STRONG)

(HIGH SUSCEPTIBILITY TO SLAKING)

(GRAY GRAYWACKE INCLUSION HIGHLY FRACTURED SLIGHTLY WEATHERED STRONG)

(GRAYWACKE INCLUSION SLIGHTLY WEATHERED, STRONG)

NOTES

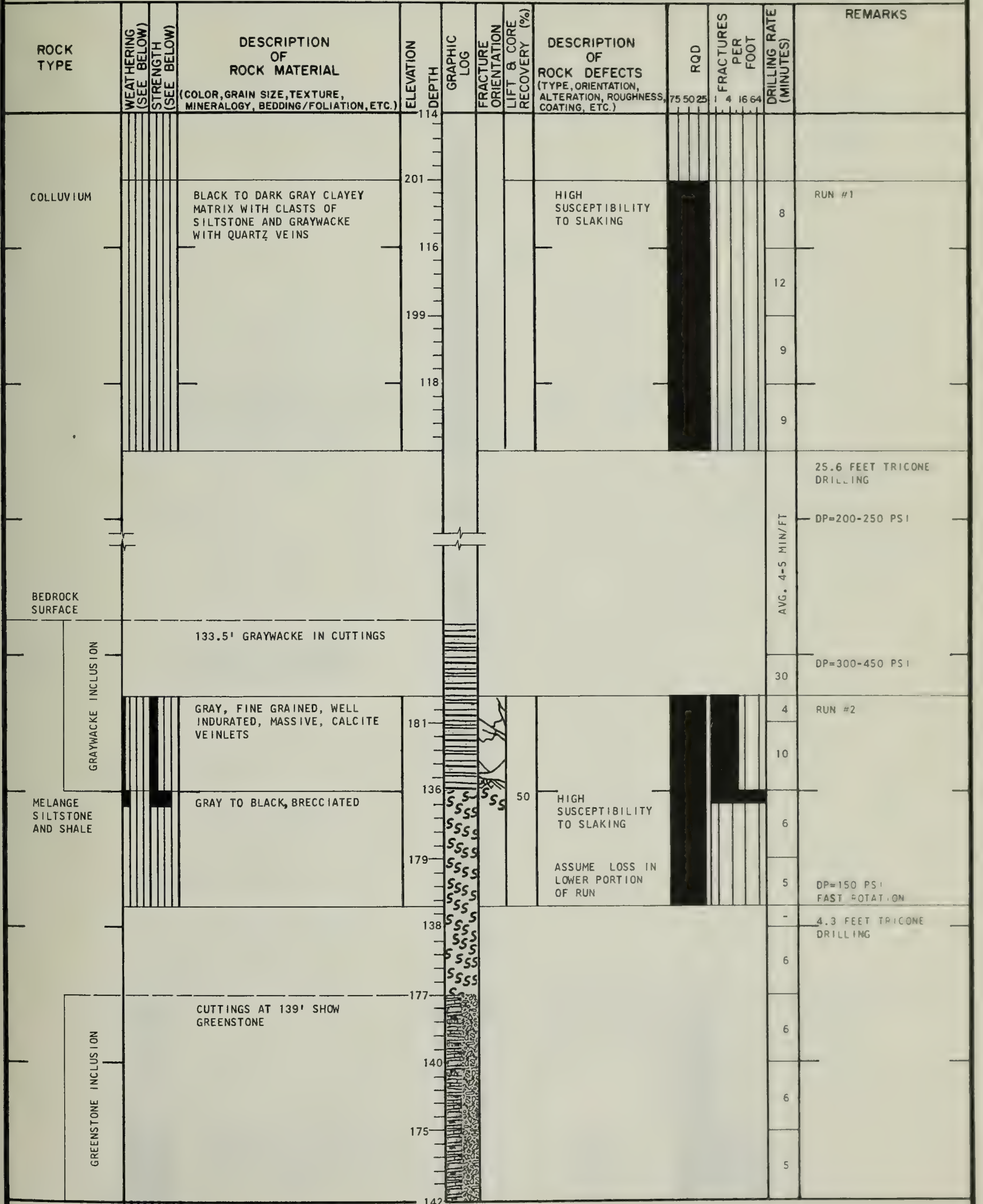
1. SAMPLING RESISTANCE [illegible] DRIVEN WITH 240# [illegible] NO. 10
2. ELEVATIONS REFER TO [illegible] DATUM AND ARE BASED ON [illegible]
3. SEE [illegible] FOR A MORE DETAILED DESCRIPTION OF THE BEDROCK

# LOG OF BORING

DAMES & MOORE

PLATE A-1AD

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 30
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION CLEMENT AND 40th. AVE.
ELEV. 316
PAGE 1 OF 9



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| | | | 114 | | | | |
| COLLUVIUM | BLACK TO DARK GRAY CLAYEY MATRIX WITH CLASTS OF SILTSTONE AND GRAYWACKE WITH QUARTZ VEINS | 201 | | | HIGH SUSCEPTIBILITY TO SLAKING | 8 | RUN #1 |
| | | | 116 | | | 12 | |
| | | 199 | | | | 9 | |
| | | | 118 | | | 9 | |
| | | | | | | AVG. 4-5 MIN/FT | 25.6 FEET TRICONE DRILLING<br>DP=200-250 PSI |
| BEDROCK SURFACE | | | | | | | |
| GRAYWACKE INCLUSION | 133.5' GRAYWACKE IN CUTTINGS | | | | | 30 | DP=300-450 PSI |
| | GRAY, FINE GRAINED, WELL INDURATED, MASSIVE, CALCITE VEINLETS | 181 | | | | 4<br>10 | RUN #2 |
| MELANGE SILTSTONE AND SHALE | GRAY TO BLACK, BRECCIATED | | 136 | 50 | HIGH SUSCEPTIBILITY TO SLAKING | 6 | |
| | | 179 | | | ASSUME LOSS IN LOWER PORTION OF RUN | 5 | DP=150 PSI<br>FAST ROTATION |
| | | | 138 | | | -<br>6 | 4.3 FEET TRICONE DRILLING |
| GREENSTONE INCLUSION | CUTTINGS AT 139' SHOW GREENSTONE | 177 | | | | 6 | |
| | | | 140 | | | 6 | |
| | | 175 | | | | 5 | |
| | | | 142 | | | | |

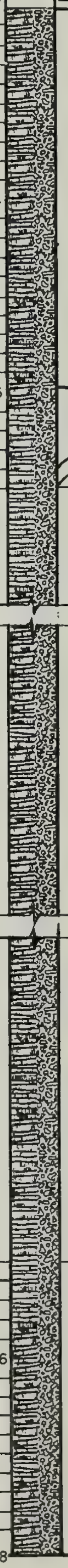
FR
SW
MW
HW
XW

VW
W
MS
S
VS

# LOG OF BORING

**DAMES & MOORE**

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 30
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION CLEMENT AND 40th. AVE.
ELEV. 316
PAGE 2 OF 9



| ROCK TYPE | WEATHERING (SEE BELOW) | STRENGTH (SEE BELOW) | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION / DEPTH | FRACTURE ORIENTATION | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | RQD 75 50 25 | FRACTURES PER FOOT 1 4 16 64 | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MELANGE<br>GREENSTONE INCLUSION | | | GREEN TO RED-BROWN, BRECCIATED SAND TO COBBLE SIZE CLASTS IN FINE GRAINED MATRIX. CLAST SIZE COARSER AT BASE<br>CP=1300 PSI - D CP=1000 PSI - A | 142<br>173<br>144<br>171<br>146 | | 20 | ASSUME RECOVERY IN LOWER PART OF RUN | | | 5<br>7<br>10<br>6<br>9 | RUN #3<br>DP=0 PSI |
| | | | SHEARED GREENSTONE OR GREENSTONE MELANGE-SUSPENDED SEDIMENT IN RETURN WATER BECOMES NOTABLE AT 156.4' | 169 | | | | | | AVG. 5 MIN/FT | 18 FEET TRICONE DRILLING<br>DP=300-400 PSI |
| | | | SHEARED GREENSTONE BRECCIA RED-BROWN CLAYEY MATRIX WITH RED-BROWN TO GREEN GREENSTONE FRAGMENTS-MINOR AMOUNTS OF SERPENTINE PRESENT | 149<br>166<br>147<br>168 | | 30 | ASSUME CORE LOSS IN UPPER PART OF RUN<br>SHEARED WITH SLICKENSIDE SURFACES<br>SUSCEPTIBILITY TO SLAKING | | | 11<br>12<br>15 | RUN #4<br>DP=200 PSI<br>DP=0 PSI |

FR SW MW HW XW
VW W MS S VS

## LOG OF BORING

**DAMES & MOORE**

PLATE A-1AD/2

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 30
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION CLEMENT AND 40th. AVE.
ELEV. 316
PAGE 3 OF 9

| ROCK TYPE | WEATHERING (SEE BELOW) | STRENGTH (SEE BELOW) | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | GRAPHIC LOG | FRACTURE ORIENTATION | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | RQD 75 50 25 | FRACTURES PER FOOT 1 4 16 64 | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GREENSTONE INCLUSION | | | | | | | | | | | | AVG. 7 MIN/FT | 17 FEET TRICONE DRILLING<br>DP=200 PSI |
| | | | GREEN AND RED-BROWN, FINE GRAINED, BRECCIATED IN UPPER AND LOWER PORTIONS, MINOR QUARTZ-PYRITE VEINING | 131<br>129 | 186<br>188 | | | 100 | HIGHLY SHEARED, MANY SLICKENSIDE SURFACES | | | 17<br>26<br>25<br>10 | RUN #5<br>DP=350 PSI |
| | | | | | | | | | | | | AVG. 7 MIN/FT | 16.7 FEET TRICONE DRILLING<br>DP=450 PSI |
| MELANGE | | | SEDIMENTARY ROCK FRAGMENTS APPEAR IN CUTTINGS AT 204.4' | | | | | | | | | | |
| SHALE AND GRAYWACKE | | | GRAY-BROWN SHALE MATRIX WITH NUMEROUS SAND TO GRAVEL SIZE CLASTS OF GRAY TO BLACK SILTY SHALE AND RELATIVELY FRESH GRAY TO GREEN GRAYWACKE. CALCITE VEINLETS OCCUR. FOLIATION AT 45°. | 111<br>109 | 206<br>208 | | | 90 | HIGH SUSCEPTIBILITY TO SLAKING<br>ASSUME CORE LOSS IN BOTTOM OF RUN | | | 17<br>23<br>20<br>12 | RUN #6<br>DP=0 PSI<br>DP=100 PSI<br>DP=0 PS |
| | | | | | | | | | | | | AVG. 7 MIN/FT | 16.6 FEET TRICONE DRILLING |

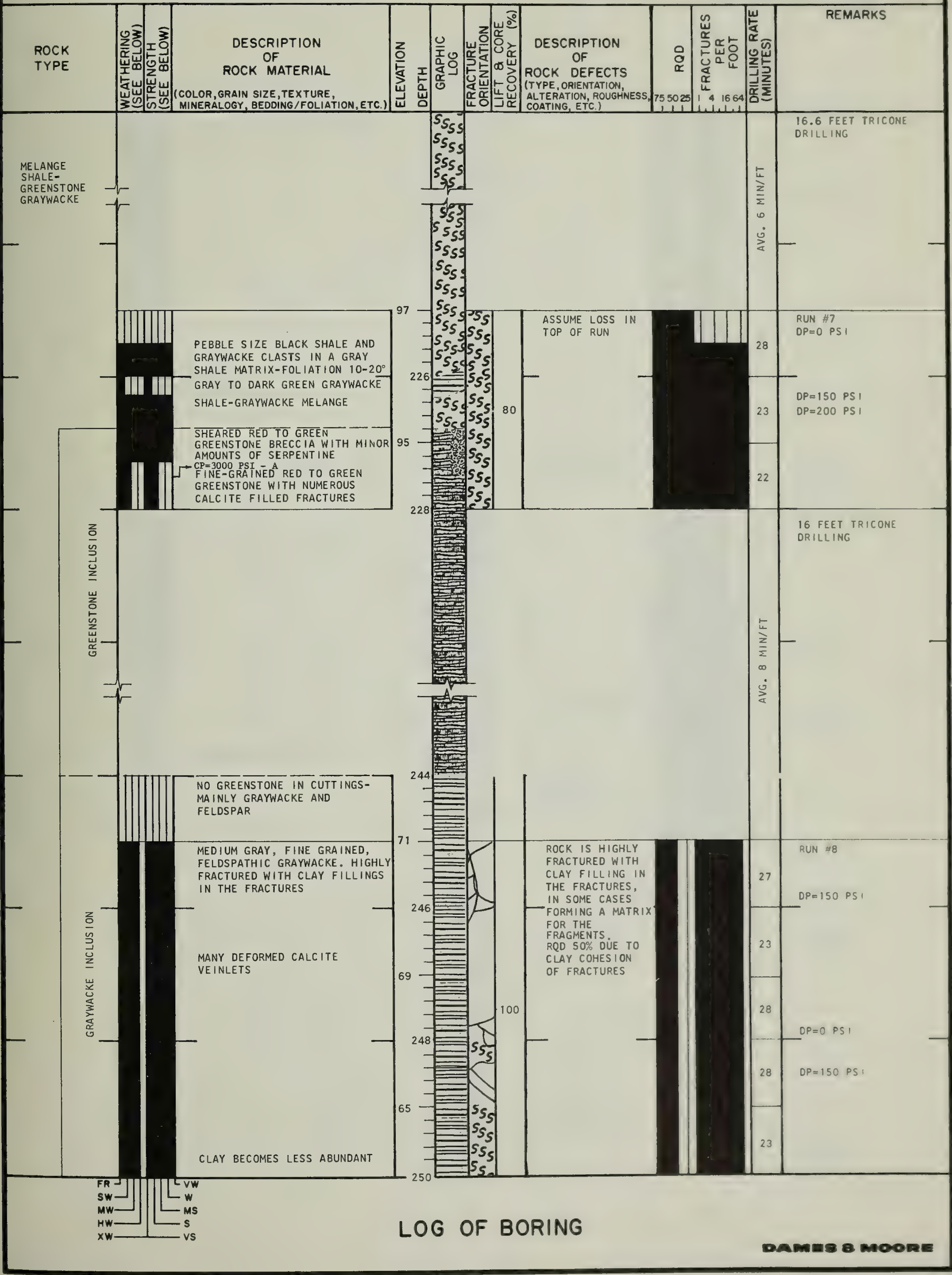
FR SW MW HW XW
VW W MS S VS

## LOG OF BORING

**DAMES & MOORE**

PLATE A-1AD/3

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 30
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION CLEMENT AND 40th. AVE.
ELEV. 316
PAGE 4 OF 9



16.6 FEET TRICONE DRILLING

PEBBLE SIZE BLACK SHALE AND GRAYWACKE CLASTS IN A GRAY SHALE MATRIX-FOLIATION 10-20°

GRAY TO DARK GREEN GRAYWACKE

SHALE-GRAYWACKE MELANGE

SHEARED RED TO GREEN GREENSTONE BRECCIA WITH MINOR AMOUNTS OF SERPENTINE

CP=3000 PSI - A

FINE-GRAINED RED TO GREEN GREENSTONE WITH NUMEROUS CALCITE FILLED FRACTURES

ASSUME LOSS IN TOP OF RUN

RUN #7
DP=0 PSI
DP=150 PSI
DP=200 PSI

16 FEET TRICONE DRILLING

NO GREENSTONE IN CUTTINGS-MAINLY GRAYWACKE AND FELDSPAR

MEDIUM GRAY, FINE GRAINED, FELDSPATHIC GRAYWACKE. HIGHLY FRACTURED WITH CLAY FILLINGS IN THE FRACTURES

MANY DEFORMED CALCITE VEINLETS

CLAY BECOMES LESS ABUNDANT

ROCK IS HIGHLY FRACTURED WITH CLAY FILLING IN THE FRACTURES, IN SOME CASES FORMING A MATRIX FOR THE FRAGMENTS, RQD 50% DUE TO CLAY COHESION OF FRACTURES

RUN #8
DP=150 PSI
DP=0 PSI
DP=150 PSI

LOG OF BORING

**DAMES & MOORE**

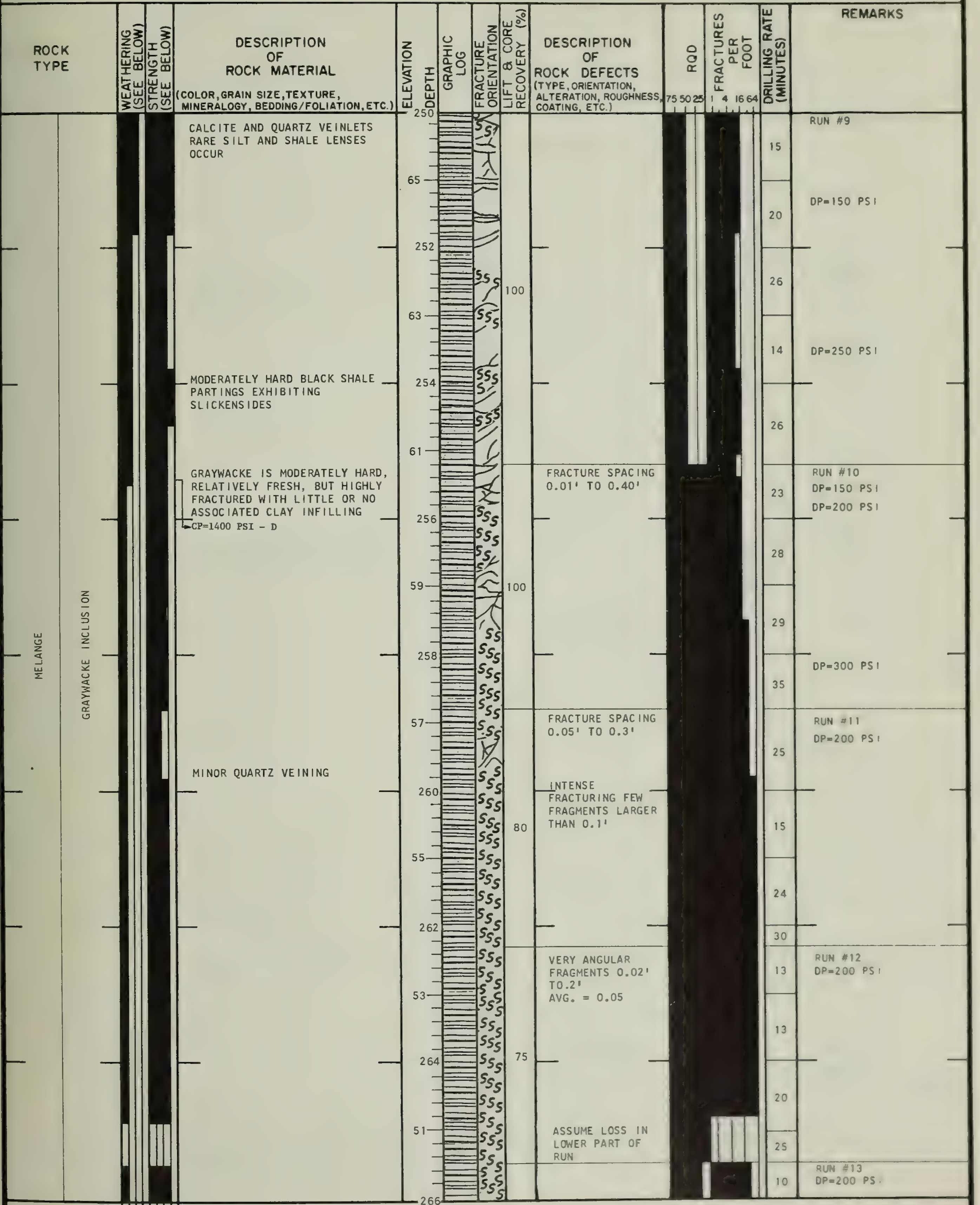
PLATE A-1AD/4

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03) BORING NO. 30

PROJECT: RICHMOND TRANSPORT SEWER ANGLE FROM HORIZONTAL 90°

DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY

LOCATION CLEMENT AND 40th. AVE. ELEV. 316 PAGE 5 OF 9



CALCITE AND QUARTZ VEINLETS RARE SILT AND SHALE LENSES OCCUR

MODERATELY HARD BLACK SHALE PARTINGS EXHIBITING SLICKENSIDES

GRAYWACKE IS MODERATELY HARD, RELATIVELY FRESH, BUT HIGHLY FRACTURED WITH LITTLE OR NO ASSOCIATED CLAY INFILLING

CP=1400 PSI - D

MINOR QUARTZ VEINING

FRACTURE SPACING 0.01' TO 0.40'

FRACTURE SPACING 0.05' TO 0.3'

INTENSE FRACTURING FEW FRAGMENTS LARGER THAN 0.1'

VERY ANGULAR FRAGMENTS 0.02' TO.2'
AVG. = 0.05

ASSUME LOSS IN LOWER PART OF RUN

RUN #9

DP=150 PSI

DP=250 PSI

RUN #10
DP=150 PSI
DP=200 PSI

DP=300 PSI

RUN #11
DP=200 PSI

RUN #12
DP=200 PSI

RUN #13
DP=200 PSI

FR SW MW HW XW

VW W MS S VS

## LOG OF BORING

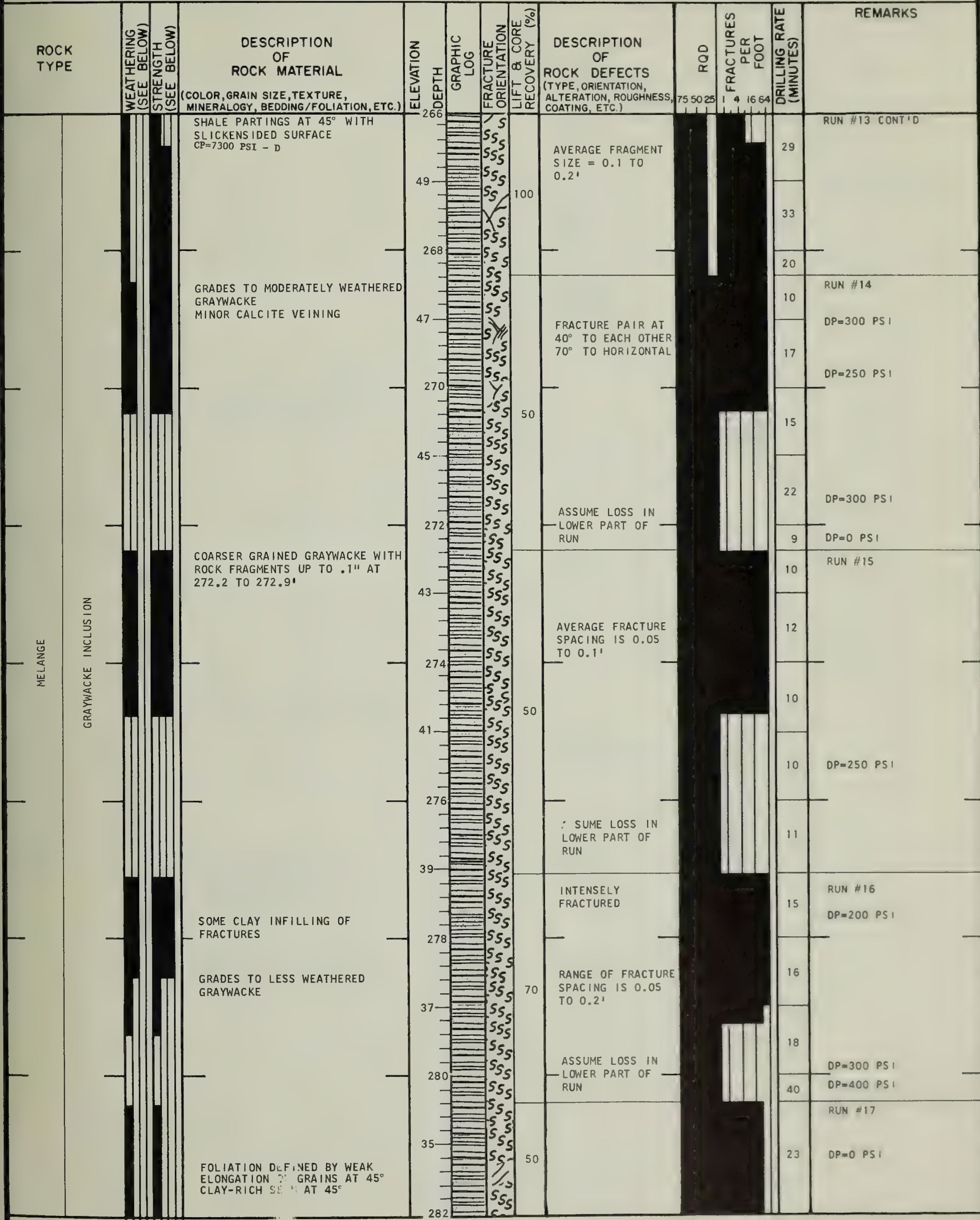
**DAMES & MOORE**

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 30

PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°

DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY

LOCATION CLEMENT AND 40th. AVE.
ELEV. 316
PAGE 6 OF 9



| ELEVATION | DEPTH | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|
| | 266 | SHALE PARTINGS AT 45° WITH SLICKENSIDED SURFACE<br>CP=7300 PSI - D | | AVERAGE FRAGMENT SIZE = 0.1 TO 0.2' | 29 | RUN #13 CONT'D |
| 49 | | | 100 | | 33 | |
| | 268 | | | | 20 | |
| | | GRADES TO MODERATELY WEATHERED GRAYWACKE<br>MINOR CALCITE VEINING | | | 10 | RUN #14 |
| 47 | | | | FRACTURE PAIR AT 40° TO EACH OTHER 70° TO HORIZONTAL | 17 | DP=300 PSI<br>DP=250 PSI |
| | 270 | | 50 | | 15 | |
| 45 | | | | | 22 | DP=300 PSI |
| | 272 | | | ASSUME LOSS IN LOWER PART OF RUN | 9 | DP=0 PSI |
| | | COARSER GRAINED GRAYWACKE WITH ROCK FRAGMENTS UP TO .1" AT 272.2 TO 272.9' | | | 10 | RUN #15 |
| 43 | | | | AVERAGE FRACTURE SPACING IS 0.05 TO 0.1' | 12 | |
| | 274 | | 50 | | 10 | |
| 41 | | | | | 10 | DP=250 PSI |
| | 276 | | | ASSUME LOSS IN LOWER PART OF RUN | 11 | |
| 39 | | SOME CLAY INFILLING OF FRACTURES | | INTENSELY FRACTURED | 15 | RUN #16<br>DP=200 PSI |
| | 278 | GRADES TO LESS WEATHERED GRAYWACKE | 70 | RANGE OF FRACTURE SPACING IS 0.05 TO 0.2' | 16 | |
| 37 | | | | | 18 | |
| | 280 | | | ASSUME LOSS IN LOWER PART OF RUN | 40 | DP=300 PSI<br>DP=400 PSI |
| 35 | | FOLIATION DEFINED BY WEAK ELONGATION OF GRAINS AT 45°<br>CLAY-RICH SEAM AT 45° | 50 | | 23 | RUN #17<br>DP=0 PSI |
| | 282 | | | | | |

FR SW MW HW XW

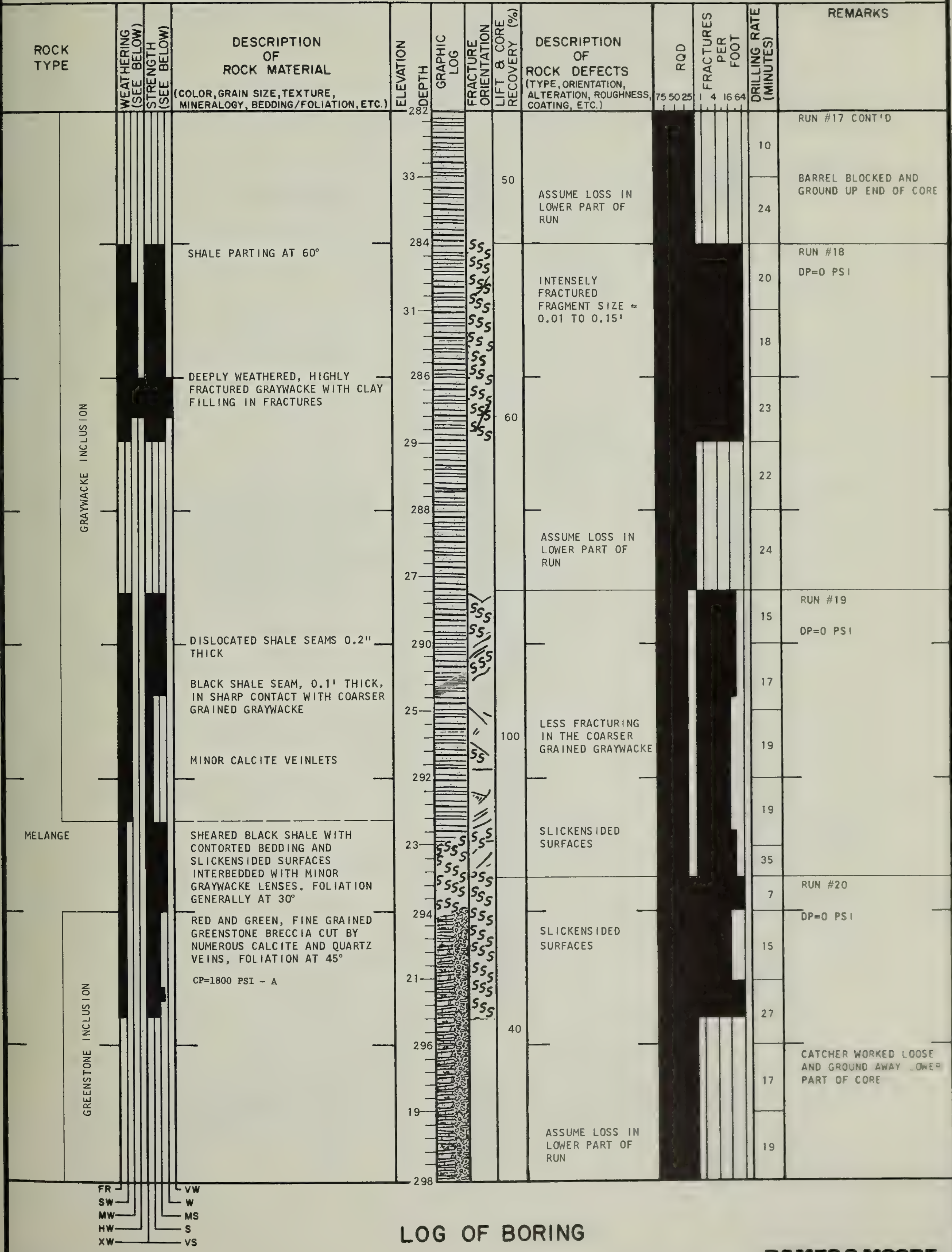
VW W MS S VS

## LOG OF BORING

**DAMES & MOORE**

PLATE A-1AD/6

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 30
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION CLEMENT AND 40th. AVE.
ELEV. 316
PAGE 7 OF 9



**DESCRIPTION OF ROCK MATERIAL**

SHALE PARTING AT 60°

DEEPLY WEATHERED, HIGHLY FRACTURED GRAYWACKE WITH CLAY FILLING IN FRACTURES

DISLOCATED SHALE SEAMS 0.2" THICK

BLACK SHALE SEAM, 0.1' THICK, IN SHARP CONTACT WITH COARSER GRAINED GRAYWACKE

MINOR CALCITE VEINLETS

SHEARED BLACK SHALE WITH CONTORTED BEDDING AND SLICKENSIDED SURFACES INTERBEDDED WITH MINOR GRAYWACKE LENSES. FOLIATION GENERALLY AT 30°

RED AND GREEN, FINE GRAINED GREENSTONE BRECCIA CUT BY NUMEROUS CALCITE AND QUARTZ VEINS, FOLIATION AT 45°

CP=1800 PSI - A

**LIFT & CORE RECOVERY (%)**

50

60

100

40

**DESCRIPTION OF ROCK DEFECTS**

ASSUME LOSS IN LOWER PART OF RUN

INTENSELY FRACTURED FRAGMENT SIZE ≈ 0.01 TO 0.15'

ASSUME LOSS IN LOWER PART OF RUN

LESS FRACTURING IN THE COARSER GRAINED GRAYWACKE

SLICKENSIDED SURFACES

SLICKENSIDED SURFACES

ASSUME LOSS IN LOWER PART OF RUN

**DRILLING RATE (MINUTES)**

10, 24, 20, 18, 23, 22, 24, 15, 17, 19, 19, 35, 7, 15, 27, 17, 19

**REMARKS**

RUN #17 CONT'D

BARREL BLOCKED AND GROUND UP END OF CORE

RUN #18
DP=0 PSI

RUN #19
DP=0 PSI

RUN #20
DP=0 PSI

CATCHER WORKED LOOSE AND GROUND AWAY LOWER PART OF CORE

## LOG OF BORING

**DAMES & MOORE**

PLATE A-1AD/7

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)

BORING NO. 30

PROJECT: RICHMOND TRANSPORT SEWER

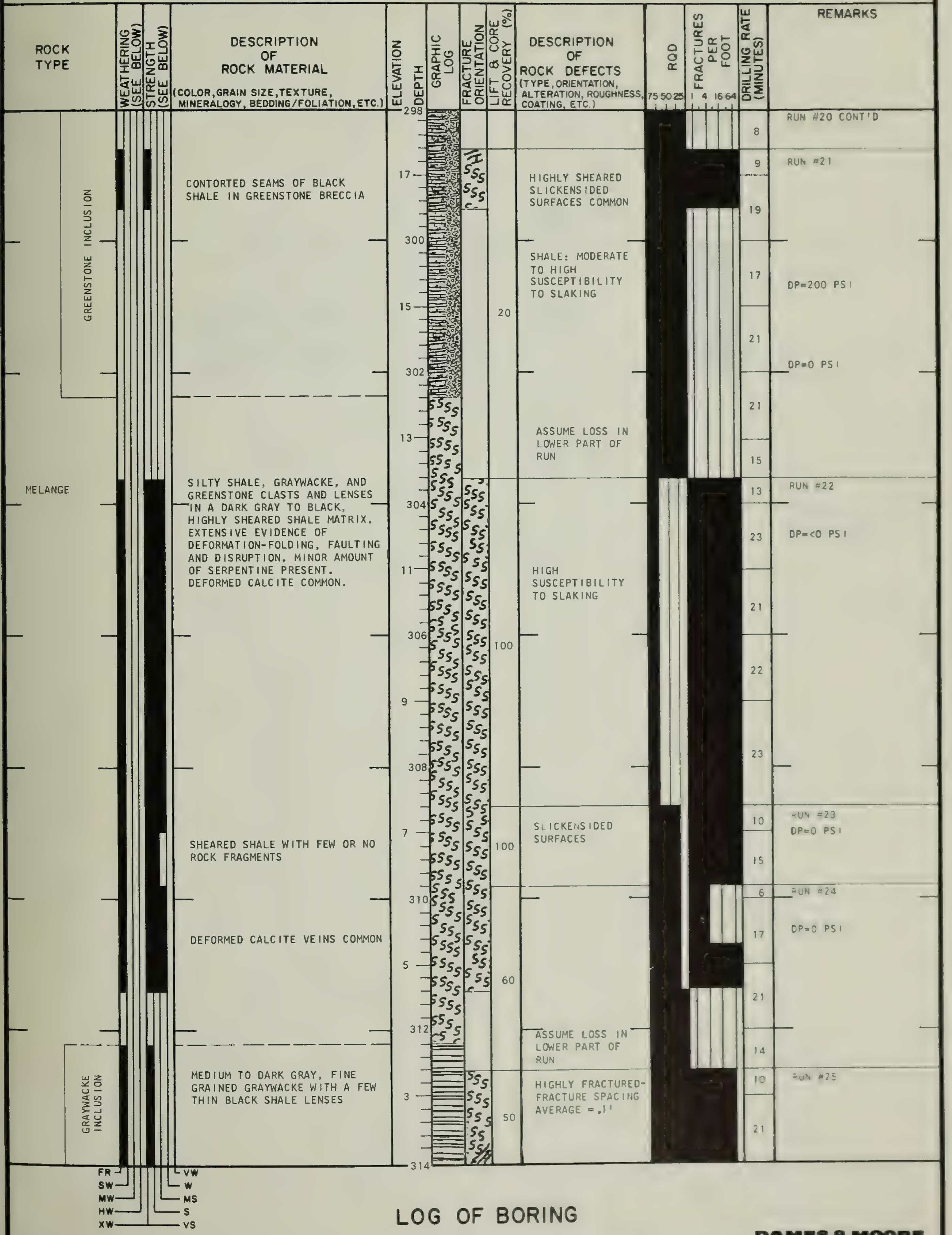
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY

ANGLE FROM HORIZONTAL 90°

LOCATION CLEMENT AND 40th. AVE.

ELEV. 316

PAGE 8 OF 9



GREENSTONE INCLUSION

CONTORTED SEAMS OF BLACK SHALE IN GREENSTONE BRECCIA

MELANGE

SILTY SHALE, GRAYWACKE, AND GREENSTONE CLASTS AND LENSES IN A DARK GRAY TO BLACK, HIGHLY SHEARED SHALE MATRIX. EXTENSIVE EVIDENCE OF DEFORMATION-FOLDING, FAULTING AND DISRUPTION. MINOR AMOUNT OF SERPENTINE PRESENT. DEFORMED CALCITE COMMON.

SHEARED SHALE WITH FEW OR NO ROCK FRAGMENTS

DEFORMED CALCITE VEINS COMMON

GRAYWACKE INCLUSION

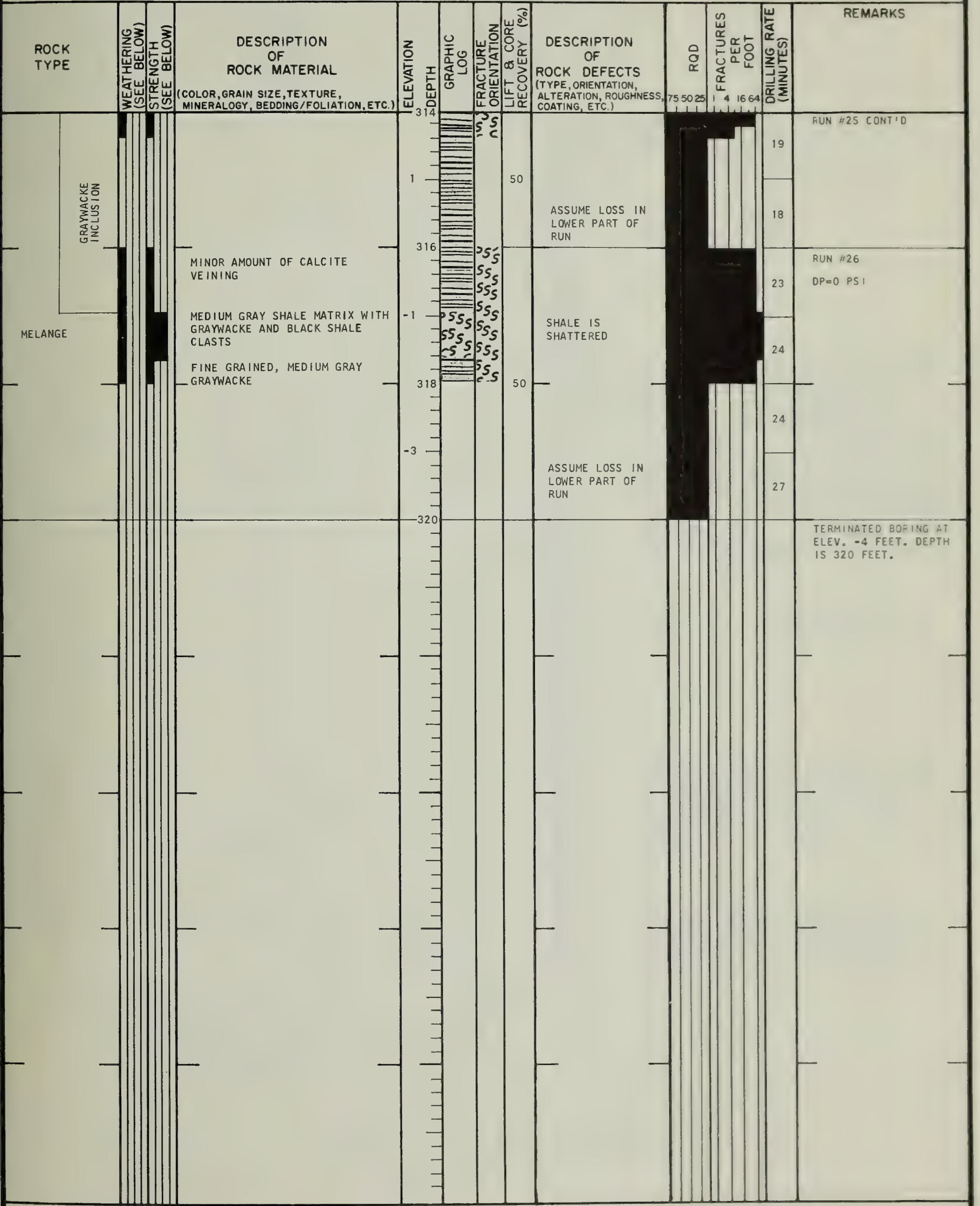
MEDIUM TO DARK GRAY, FINE GRAINED GRAYWACKE WITH A FEW THIN BLACK SHALE LENSES

| Lift & core recovery (%) | Description of rock defects | Drilling rate (minutes) | Remarks |
|---|---|---|---|
|  |  | 8 | RUN #20 CONT'D |
| 20 | HIGHLY SHEARED SLICKENSIDED SURFACES COMMON<br>SHALE: MODERATE TO HIGH SUSCEPTIBILITY TO SLAKING<br>ASSUME LOSS IN LOWER PART OF RUN | 9<br>19<br>17<br>21<br>21<br>15 | RUN #21<br>DP=200 PSI<br>DP=0 PSI |
| 100 | HIGH SUSCEPTIBILITY TO SLAKING | 13<br>23<br>21<br>22<br>23 | RUN #22<br>DP=<0 PSI |
| 100 | SLICKENSIDED SURFACES | 10<br>15 | RUN #23<br>DP=0 PSI |
| 60 | ASSUME LOSS IN LOWER PART OF RUN | 6<br>17<br>21<br>14 | RUN #24<br>DP=0 PSI |
| 50 | HIGHLY FRACTURED-FRACTURE SPACING AVERAGE = .1' | 10<br>21 | RUN #25 |

LOG OF BORING

DAMES & MOORE

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 30
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION CLEMENT AND 40th. AVE.
ELEV. 316
PAGE 9 OF 9



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| GRAYWACKE INCLUSION | | | 314 | | | 19 | RUN #25 CONT'D |
| | | 1 | | 50 | ASSUME LOSS IN LOWER PART OF RUN | 18 | |
| | MINOR AMOUNT OF CALCITE VEINING | | 316 | | | 23 | RUN #26<br>DP=0 PSI |
| MELANGE | MEDIUM GRAY SHALE MATRIX WITH GRAYWACKE AND BLACK SHALE CLASTS<br>FINE GRAINED, MEDIUM GRAY GRAYWACKE | -1 | | | SHALE IS SHATTERED | 24 | |
| | | | 318 | 50 | | 24 | |
| | | -3 | | | ASSUME LOSS IN LOWER PART OF RUN | 27 | |
| | | | 320 | | | | TERMINATED BORING AT ELEV. -4 FEET. DEPTH IS 320 FEET. |

FR — SW — MW — HW — XW
VW — W — MS — S — VS

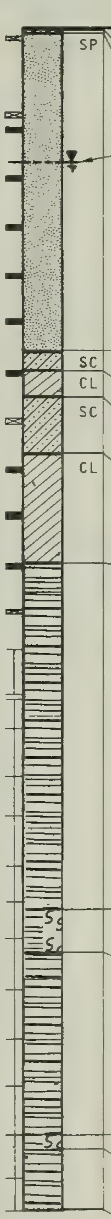
LOG OF BORING

DAMES & MOORE

PLATE A-1AD/9

## BORING 31
DRILLED 8/21-25/78

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS | | SHEAR STRENGTH TEST RESULTS | | | | | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD.PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | LABORATORY | | | FIELD | | | | | |
| | | | | LIQUID LIMIT | PLASTIC LIMIT | TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | TORVANE (PSF) | PENETROMETER (PSF) | | | | |
| +130 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | GRAB | | |
| +120 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | GRAB | | |
| | | 6 | 112 | | | | | | | | | U-1 | 100 | 27 |
| +110 | | 7 | 106 | | | | | | | | | U-1 | 100 | 34 |
| | | 12 | 109 | | | | | | | | | U-1 | 100 | 52 |
| +100 | SA (1%) | 17 | 105 | | | | | | | | | U-1 | 100 | 67 |
| | SA (1%) | 17 | 113 | | | DS/CU | 3500 | 2400 | | | | U-1 | 80 | 51 |
| +90 | | 24 | 104 | 41 | 17 | UC | 0 | 1810 | | | | U-1 | 100 | 16 |
| | SA (27%) | 17 | 114 | | | DS/CU | 3900 | 3670 | | | | U-1 | 100 | 58 |
| +80 | | 21 | 108 | | | TX/CU | 4200 | 3970 | | | | U-1 | 100 | 34 |
| | | 14 | 113 | | | TX/CU | 4500 | 4920 | | | | U-1 | 100 | 41 |
| +70 | | 13 | 120 | | | TX/CU | 4700 | 2000 | | | | U-1 | 100 | 50/6" |
| | | 11 | 121 | | | | | | | | | U-1 | 100 | 100/6" |
| +60 | | | | | | | | | | | | | | |
| | | | | | | | | | | | 11<br>10<br>10<br>11<br>7<br>15<br>19<br>19<br>18<br>20<br>17<br>17<br>18<br>15<br>17<br>19<br>20<br>17<br>16<br>21<br>20<br>19<br>16<br>15<br>15<br>17 | NX | 100 | |
| | | | | | | | | | | | | NX | 100 | |
| +50 | | | | | | | | | | | | NX | 100 | |
| | | | | | | | | | | | | NX | 100 | |
| | | | | | | | | | | | | NX | 100 | |
| +40 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | NX | 100 | |
| | | | | | | | | | | | | NX | 75 | |
| +30 | | | | | | | | | | | | | | |
| | | | | | | | | | | | 11<br>14<br>17<br>16<br>16<br>15<br>14<br>15<br>14<br>16<br>17<br>16<br>17<br>17<br>15<br>16<br>18<br>17<br>17<br>19<br>16<br>13<br>14<br>17<br>15<br>13<br>15 | NX | 100 | |
| | | | | | | | | | | | | NX | 100 | |
| +20 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | NX | 100 | |
| | | | | | | | | | | | | NX | 75 | |
| +10 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | NX | 100 | |
| | | | | | | | | | | | | NX | 100 | |
| 0 | | | | | | | | | | | | | | |



ELEVATION +125'

0.2' ASPHALTIC CONCRETE

0.5' CONCRETE

GRAY FINE SAND (DUNE SAND)

(MEDIUM DENSE)
(WATER LEVEL, 11/15/78)
(GRADING DARK GRAY-BROWN)
(MEDIUM DENSE TO DENSE)

(DENSE)

DARK GRAY AND ORANGE-BROWN SILTY CLAYEY FINE SAND (COLMA FORMATION)

GRAY SILTY CLAY WITH TRACE OF FINE SAND, BLACK DECAYED VEGETATION (STIFF)

REDDISH BROWN CLAYEY FINE SAND WITH TRACE BLACK ORGANIC SPOTS, IRON OXIDE STAINING (VERY DENSE)

LIGHT BROWN FINE SANDY SILTY CLAY WITH ORANGE BROWN MOTTLING, OCCASIONAL EXTREMELY WEATHERED ROUNDED PEBBLES (VERY STIFF)(COLLUVIUM)
(GRADING WITH LARGE PIECES OF HIGHLY WEATHERED SANDSTONE @ EL. +75')

DARK BROWN GRAYWACKE, EXTREMELY WEATHERED, VERY WEAK, THICK BEDDED
(GRADING HIGHLY WEATHERED, WITH LIGHT BROWN CLAY-FILLED SEAMS, WEAK)

(GRADING MODERATELY WEATHERED, MODERATELY STRONG, WITH OCCASIONAL CLAY-FILLED SEAMS)

SHEAR ZONE. HIGHLY WEATHERED GRAYWACKE WITH A CLAY MATRIX, WEAK TO VERY WEAK. SOME SLICKENSIDED SHALE AND LIGNITE STRINGERS.

GRAY GRAYWACKE, FRESH TO SLIGHTLY WEATHERED. STRONG, THICK BEDDED, RQD = 80
(GRADING MODERATELY STRONG AT EL. +26')
(OCCASIONAL SHALE LAMINATIONS, SLICKENSIDED)

(RQD FALLING TO 55%)

SHEAR ZONE. CLAY AND SHEARED SHALE, EXTREMELY WEATHERED, VERY WEAK, SLAKES READILY

GRAY GRAYWACKE, FRESH TO SLIGHTLY WEATHERED. STRONG, THICK BEDDED, OCCASIONAL SHALE LAMINATION.

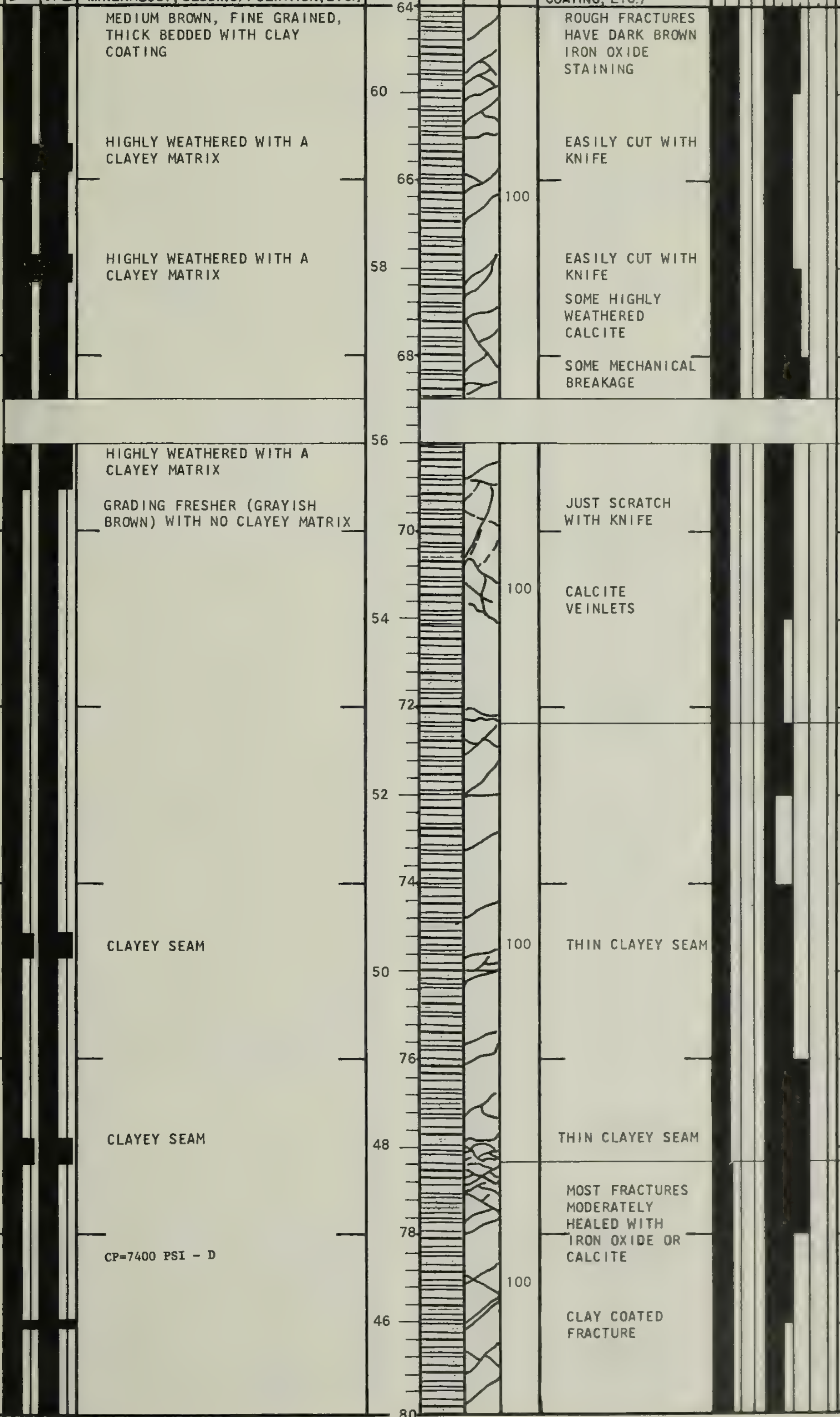
NOTES:

1. SAMPLING RESISTANCE:
   U DRIVEN WITH 240# SLIPJARS FALLING 18"
2. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED ON NEARBY SURVEY BENCHMARKS.
3. REFER TO THE FOLLOWING GEOLOGIC LOGS FOR A MORE DETAILED DESCRIPTION OF THE BEDROCK.

# LOG OF BORING

**DAMES & MOORE**

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
PROJECT: RICHMOND TRANSPORT SEWER
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION: 28th. AVE. NEAR EL CAMINO DEL MAR
ELEV. 125
BORING NO. 31
ANGLE FROM HORIZONTAL 90°
PAGE 1 OF 4



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| GRAYWACKE | MEDIUM BROWN, FINE GRAINED, THICK BEDDED WITH CLAY COATING | | 64 | | ROUGH FRACTURES HAVE DARK BROWN IRON OXIDE STAINING | 11 | RUN #1<br>DP = 100 PSI |
| | HIGHLY WEATHERED WITH A CLAYEY MATRIX | 60 | | | EASILY CUT WITH KNIFE | 10 | |
| | | | 66 | 100 | | 10 | |
| | HIGHLY WEATHERED WITH A CLAYEY MATRIX | 58 | | | EASILY CUT WITH KNIFE<br>SOME HIGHLY WEATHERED CALCITE | 11 | |
| | | | 68 | | SOME MECHANICAL BREAKAGE | 7 | |
| | | | | | | - | TRICONE REAM SET NX CASING |
| | HIGHLY WEATHERED WITH A CLAYEY MATRIX<br>GRADING FRESHER (GRAYISH BROWN) WITH NO CLAYEY MATRIX | 56 | | | JUST SCRATCH WITH KNIFE | 15 | RUN #2<br>LARGE INTACT SECTION OF CORE DROPPED. BROKE ALONG SEMI-HEALED FRACTURES, RQD BETTER THAN CORE DEMONSTRATES |
| | | | 70 | 100 | CALCITE VEINLETS | 19 | |
| | | 54 | | | | 19 | |
| | | | 72 | | | - | |
| | | | | | | 18 | RUN #3 |
| | | 52 | | | | 20 | |
| | CLAYEY SEAM | | 74 | 100 | THIN CLAYEY SEAM | 17 | |
| | | 50 | | | | 17 | |
| | | | 76 | | | 18 | |
| | CLAYEY SEAM | 48 | | | THIN CLAYEY SEAM | - | |
| | | | | | MOST FRACTURES MODERATELY HEALED WITH IRON OXIDE OR CALCITE | 15 | RUN #4<br>DP = 150 PSI |
| | CP=7400 PSI - D | | 78 | 100 | | 17 | |
| | | 46 | | | CLAY COATED FRACTURE | | |
| | | | 80 | | | 19 | |

FR SW MW HW XW
VW W MS S VS

## LOG OF BORING

DAMES & MOORE

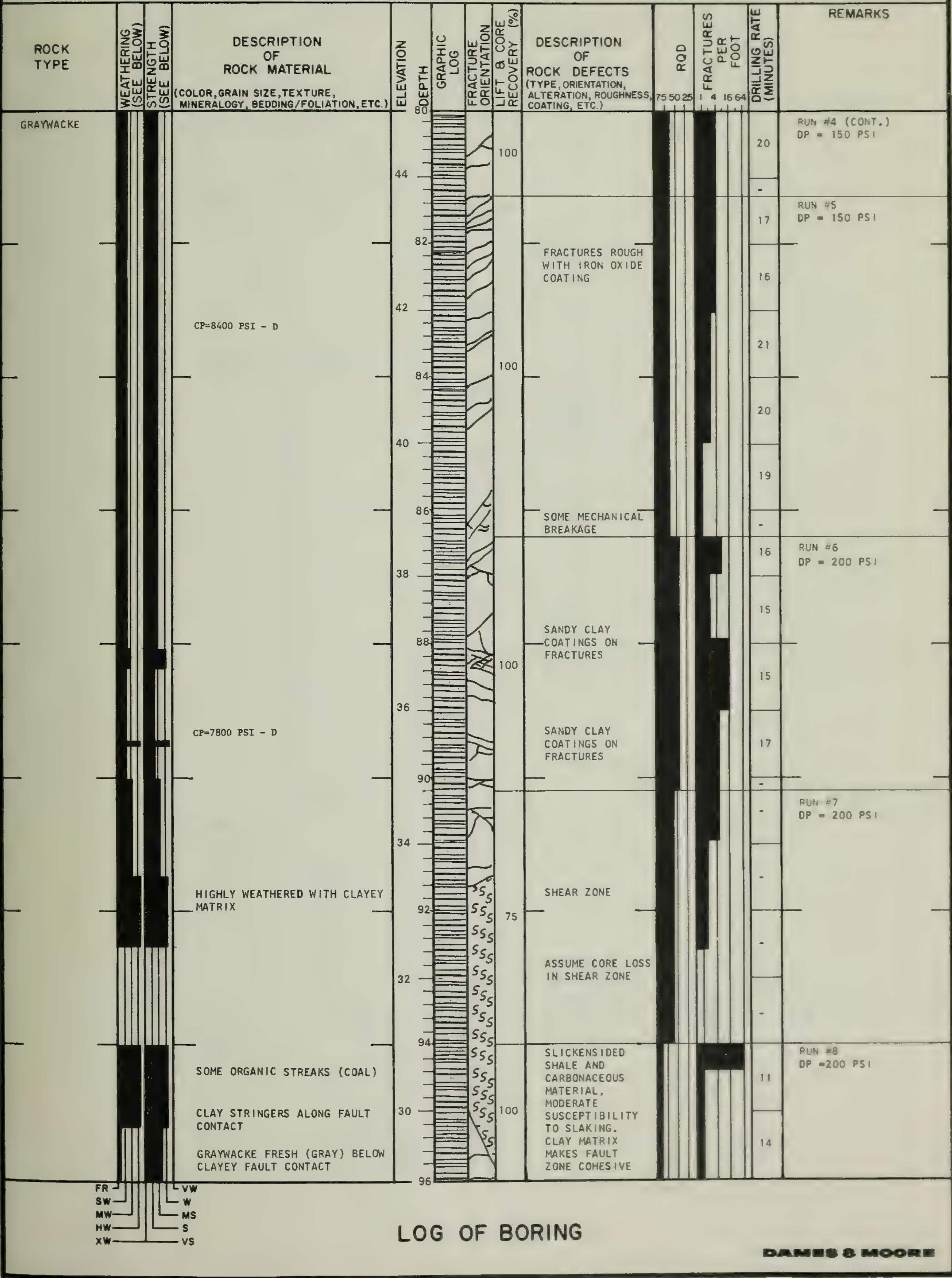
PLATE A-1AE/1

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03) BORING NO. 31

PROJECT: RICHMOND TRANSPORT SEWER

DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY ANGLE FROM HORIZONTAL 90°

LOCATION 28th. AVE. NEAR EL CAMINO DEL MAR ELEV. 125 PAGE 2 OF 4



GRAYWACKE

CP=8400 PSI - D

CP=7800 PSI - D

HIGHLY WEATHERED WITH CLAYEY MATRIX

SOME ORGANIC STREAKS (COAL)

CLAY STRINGERS ALONG FAULT CONTACT

GRAYWACKE FRESH (GRAY) BELOW CLAYEY FAULT CONTACT

FRACTURES ROUGH WITH IRON OXIDE COATING

SOME MECHANICAL BREAKAGE

SANDY CLAY COATINGS ON FRACTURES

SANDY CLAY COATINGS ON FRACTURES

SHEAR ZONE

ASSUME CORE LOSS IN SHEAR ZONE

SLICKENSIDED SHALE AND CARBONACEOUS MATERIAL, MODERATE SUSCEPTIBILITY TO SLAKING. CLAY MATRIX MAKES FAULT ZONE COHESIVE

RUN #4 (CONT.)
DP = 150 PSI

RUN #5
DP = 150 PSI

RUN #6
DP = 200 PSI

RUN #7
DP = 200 PSI

RUN #8
DP =200 PSI

# LOG OF BORING

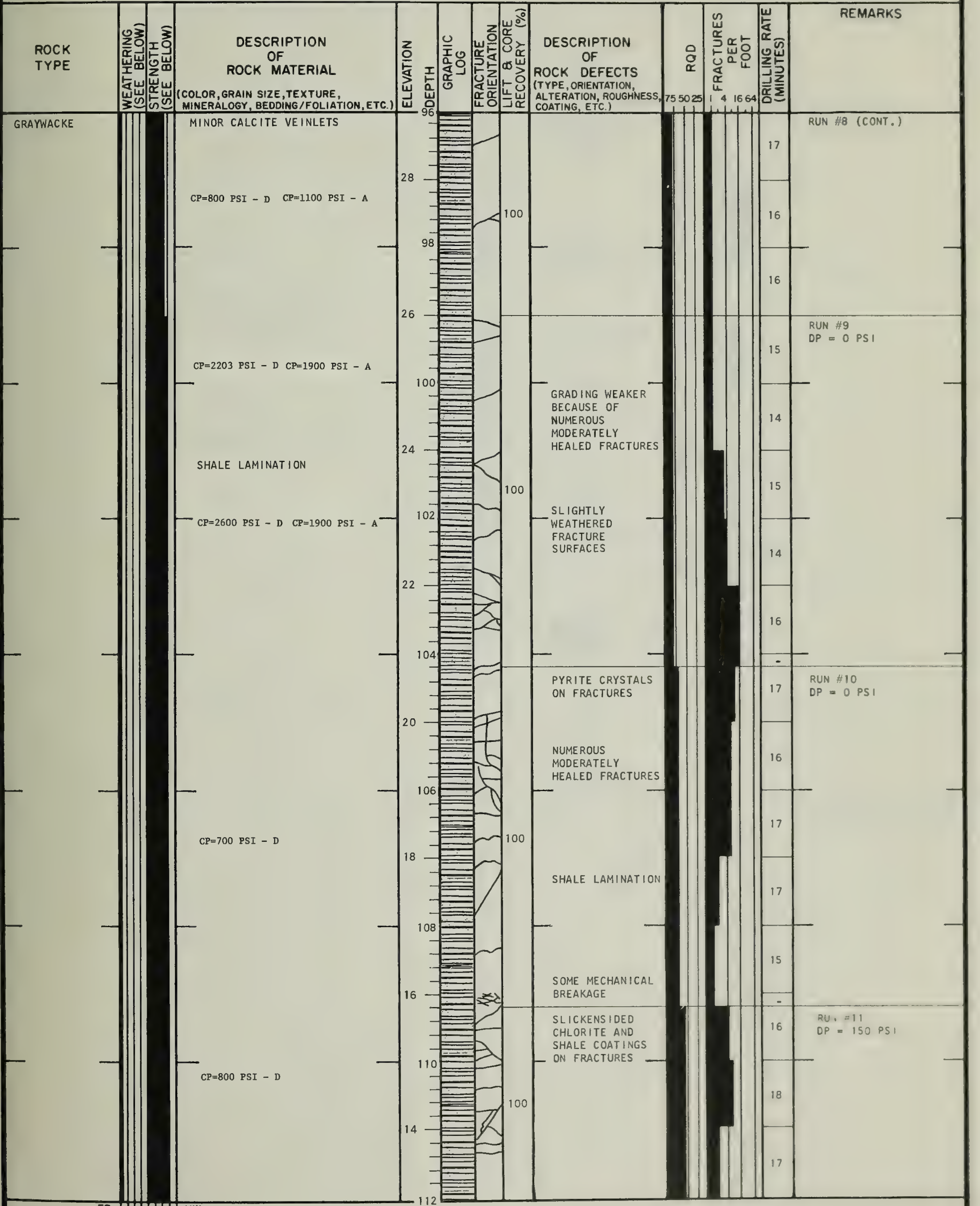
DAMES & MOORE

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)  BORING NO. 31

PROJECT: RICHMOND TRANSPORT SEWER  ANGLE FROM HORIZONTAL 90°

DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY

LOCATION 28th. AVE. NEAR EL CAMINO DEL MAR  ELEV. 125  PAGE 3 OF 4



ROCK TYPE: GRAYWACKE

DESCRIPTION OF ROCK MATERIAL:

- MINOR CALCITE VEINLETS
- CP=800 PSI - D CP=1100 PSI - A
- CP=2203 PSI - D CP=1900 PSI - A
- SHALE LAMINATION
- CP=2600 PSI - D CP=1900 PSI - A
- CP=700 PSI - D
- CP=800 PSI - D

LIFT & CORE RECOVERY (%): 100, 100, 100, 100

DESCRIPTION OF ROCK DEFECTS:

- GRADING WEAKER BECAUSE OF NUMEROUS MODERATELY HEALED FRACTURES
- SLIGHTLY WEATHERED FRACTURE SURFACES
- PYRITE CRYSTALS ON FRACTURES
- NUMEROUS MODERATELY HEALED FRACTURES
- SHALE LAMINATION
- SOME MECHANICAL BREAKAGE
- SLICKENSIDED CHLORITE AND SHALE COATINGS ON FRACTURES

DRILLING RATE (MINUTES): 17, 16, 16, 15, 14, 15, 14, 16, -, 17, 16, 17, 17, 15, -, 16, 18, 17

REMARKS:

- RUN #8 (CONT.)
- RUN #9
  DP = 0 PSI
- RUN #10
  DP = 0 PSI
- RUN #11
  DP = 150 PSI

FR SW MW HW XW

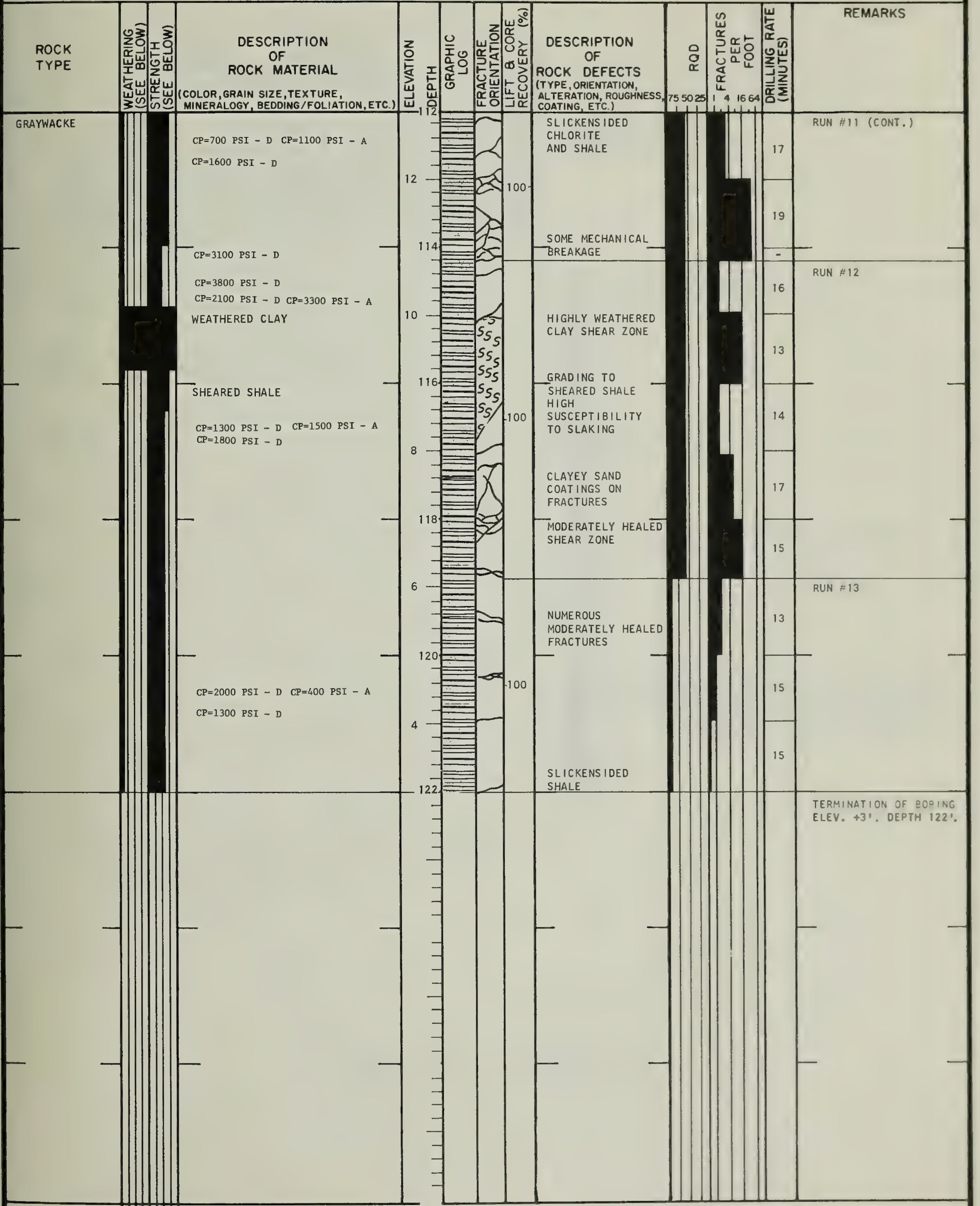
VW W MS S VS

## LOG OF BORING

DAMES & MOORE

PLATE A-IAE/3

CLIENT: CITY & COUNTY OF SAN FRANCISCO (D&M JOB 185-131-03)
BORING NO. 31
PROJECT: RICHMOND TRANSPORT SEWER
ANGLE FROM HORIZONTAL 90°
DRILLING METHOD: ROTARY WASH (NX-CORING) WITH REVERT SLURRY
LOCATION 28th. AVE. NEAR EL CAMINO DEL MAR
ELEV. 125
PAGE 4 OF 4



| ROCK TYPE | DESCRIPTION OF ROCK MATERIAL (COLOR, GRAIN SIZE, TEXTURE, MINERALOGY, BEDDING/FOLIATION, ETC.) | ELEVATION | DEPTH | LIFT & CORE RECOVERY (%) | DESCRIPTION OF ROCK DEFECTS (TYPE, ORIENTATION, ALTERATION, ROUGHNESS, COATING, ETC.) | DRILLING RATE (MINUTES) | REMARKS |
|---|---|---|---|---|---|---|---|
| GRAYWACKE | CP=700 PSI - D CP=1100 PSI - A<br>CP=1600 PSI - D | | 112 | | SLICKENSIDED CHLORITE AND SHALE | 17 | RUN #11 (CONT.) |
| | | 12 | | 100 | | 19 | |
| | CP=3100 PSI - D | | 114 | | SOME MECHANICAL BREAKAGE | - | |
| | CP=3800 PSI - D<br>CP=2100 PSI - D CP=3300 PSI - A | | | | | 16 | RUN #12 |
| | WEATHERED CLAY | 10 | | | HIGHLY WEATHERED CLAY SHEAR ZONE | 13 | |
| | SHEARED SHALE<br>CP=1300 PSI - D CP=1500 PSI - A<br>CP=1800 PSI - D | | 116 | 100 | GRADING TO SHEARED SHALE HIGH SUSCEPTIBILITY TO SLAKING | 14 | |
| | | 8 | | | CLAYEY SAND COATINGS ON FRACTURES | 17 | |
| | | | 118 | | MODERATELY HEALED SHEAR ZONE | 15 | |
| | | 6 | | | NUMEROUS MODERATELY HEALED FRACTURES | 13 | RUN #13 |
| | CP=2000 PSI - D CP=400 PSI - A<br>CP=1300 PSI - D | | 120 | 100 | | 15 | |
| | | 4 | | | SLICKENSIDED SHALE | 15 | |
| | | | 122 | | | | TERMINATION OF BORING ELEV. +3'. DEPTH 122'. |

FR SW MW HW XW
VW W MS S VS

## LOG OF BORING

**DAMES & MOORE**

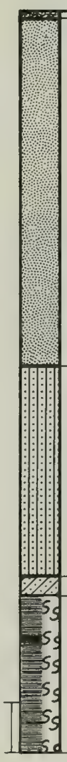
PLATE A-1AE/4

## BORING 32
DRILLED 8/28/78

| ELEVATION IN FEET | OTHER TESTS & INFORMATION | MOISTURE CONTENT (%) | DRY DENSITY (PCF) | ATTERBERG LIMITS | | SHEAR STRENGTH TEST RESULTS | | | | | CORING RATE (MIN./FT.) | SAMPLER TYPE | SAMPLER RECOVERY (%) | SAMPLING RESISTANCE (BLOWS/FT)or(HYD.PRESS.,PSI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | LABORATORY | | | FIELD | | | | | |
| | | | | LIQUID LIMIT | PLASTIC LIMIT | TYPE OF TEST | NORMAL OR CONFINING PRESSURE (PSF) | PEAK SHEAR STRENGTH (PSF) | TORVANE (PSF) | PENETROMETER (PSF) | | | | |
| +260 | | | | | | | | | | | | | | |
| +250 | | | | | | | | | | | | | | |
| +240 | | | | | | | | | | | | | | |
| +230 | | | | | | | | | | | | | | |
| +220 | | | | | | | | | | | | | | |
| +210 | | | | | | | | | | | | | | |
| +200 | | | | | | | | | | | | | | |
| +190 | | | | | | | | | | | | | | |
| +180 | | | | | | | | | | | 10<br>13<br>15<br>14<br>16 | NX | 50 | |
| +170 | | | | | | | | | | | | | | |

NOTE:

1. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED ON NEARBY SURVEYED BENCHMARKS.
2. WATER LEVEL NOT MEASURED



ELEVATION +254'

CONCRETE PAVEMENT, 6"

SP BROWN FINE SAND (DUNE SAND)

SM DARK GRAY-BROWN SILTY FINE SAND (COLMA FORMATION)
(LESS SILTY BETWEEN EL. +215 AND +213)
(GRADING DARK REDDISH BROWN)
(GRADING LIGHT GRAY)

SC LIGHT GRAY CLAYEY FINE SAND (COLLUVIUM)
(GRADING ORANGE-BROWN, WITH SHALE FRAGMENTS)

DARK GRAY TO BLACK SHALE (FRANCISCAN MELANGE) HIGHLY FRACTURED WITH BROWN AND LIGHT GRAY CLAY MATRIX. HIGHLY WEATHERED, VERY WEAK. SLICKENSIDED.

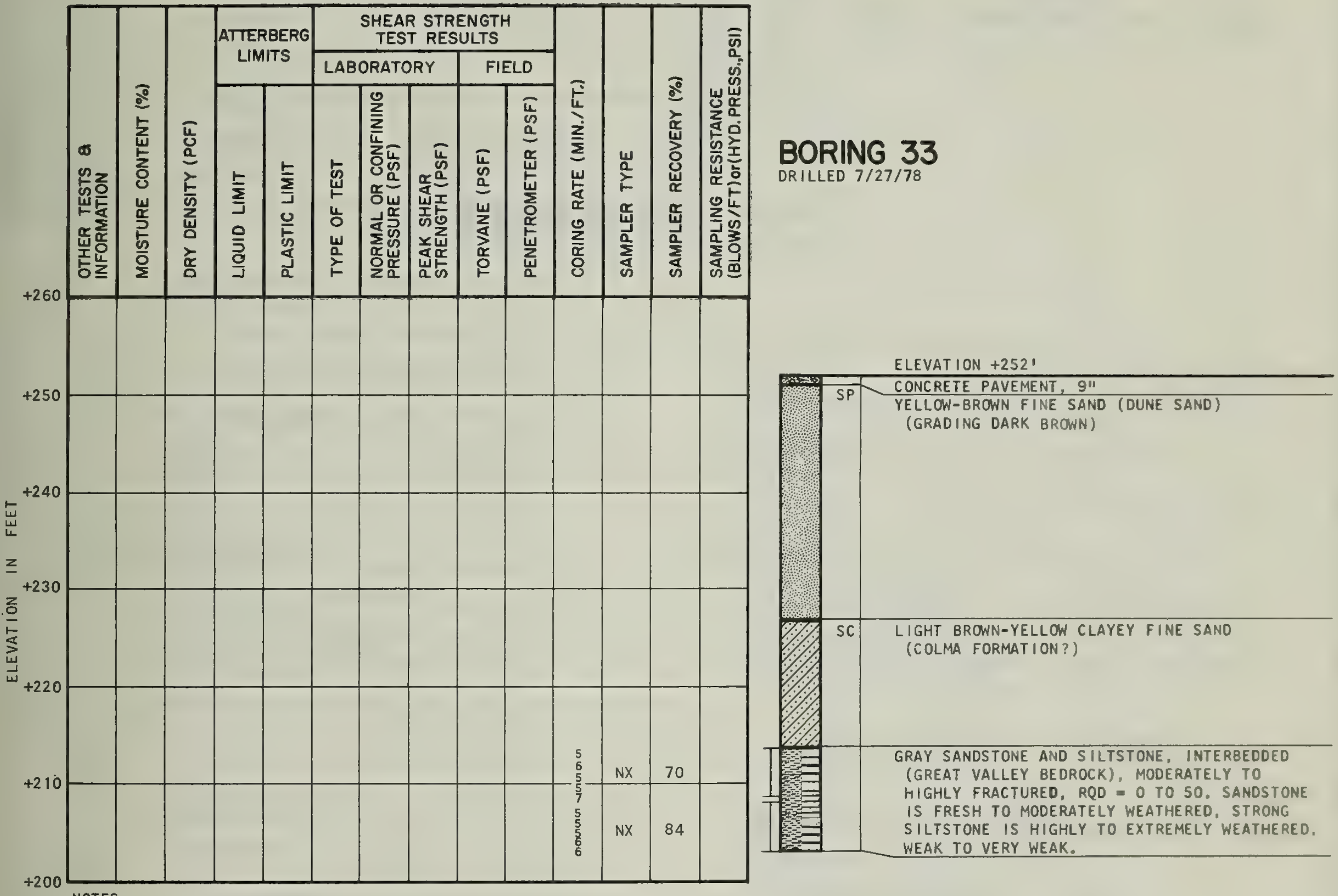
# LOG OF BORING

DAMES & MOORE

PLATE A-IAF

## BORING 33

DRILLED 7/27/78



ELEVATION +252'

CONCRETE PAVEMENT, 9"

SP YELLOW-BROWN FINE SAND (DUNE SAND) (GRADING DARK BROWN)

SC LIGHT BROWN-YELLOW CLAYEY FINE SAND (COLMA FORMATION?)

GRAY SANDSTONE AND SILTSTONE, INTERBEDDED (GREAT VALLEY BEDROCK), MODERATELY TO HIGHLY FRACTURED, RQD = 0 TO 50. SANDSTONE IS FRESH TO MODERATELY WEATHERED, STRONG SILTSTONE IS HIGHLY TO EXTREMELY WEATHERED, WEAK TO VERY WEAK.

NOTES:

1. ELEVATIONS REFER TO S.F. DATUM AND ARE BASED ON NEARBY SURVEYED BENCHMARKS.
2. WATER LEVEL NOT MEASURED

# LOG OF BORING

DAMES & MOORE

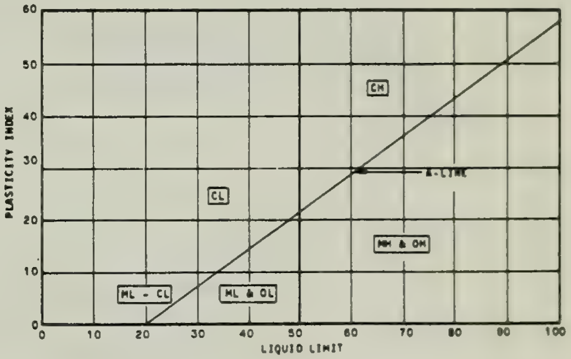
| SYMBOL | LETTER | DESCRIPTION | MAJOR DIVISIONS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ▨ | GW | WELL-GRADED GRAVELS OR GRAVEL-SAND MIXTURES, LITTLE OR NO FINES | CLEAN GRAVELS (little or no fines) | GRAVELS | MORE THAN HALF OF COARSE FRACTION IS LARGER THAN NO.4 SIEVE SIZE | for visual classification, the 1/4" size may be used as equivalent to the no. 4 sieve size. | COARSE-GRAINED SOILS | MORE THAN HALF OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE | the no. 200 U.S. standard sieve size is about the smallest particle visible to the naked eye |
| ▨ | GP | POORLY-GRADED GRAVELS OR GRAVEL-SAND MIXTURES. LITTLE OR NO FINES | | | | | | | |
| ▨ | GM | SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES | GRAVELS WITH FINES (appreciable amount of fines) | | | | | | |
| ▨ | GC | CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES | | | | | | | |
| ▨ | SW | WELL-GRADED SAND OR GRAVELLY SANDS, LITTLE OR NO FINES | CLEAN SANDS (little or no fines) | SANDS | MORE THAN HALF OF COARSE FRACTION IS SMALLER THAN NO.4 SIEVE SIZE | | | | |
| ▨ | SP | POORLY-GRADED SANDS OR GRAVELLY SANDS, LITTLE OR NO FINES | | | | | | | |
| ▨ | SM | SILTY SANDS, SAND-SILT MIXTURES | SAND WITH FINES (appreciable amount of fines) | | | | | | |
| ▨ | SC | CLAYEY SANDS, SAND-CLAY MIXTURES | | | | | | | |
| ▨ | ML | INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY | SILTS AND CLAYS<br>LIQUID LIMIT LESS THAN 50 | | | | FINE-GRAINED SOILS | MORE THAN HALF OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE | |
| ▨ | CL | INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS | | | | | | | |
| ▨ | OL | ORGANIC SILTS AND ORGANIC SILT-CLAYS OF LOW PLASTICITY | | | | | | | |
| ▨ | MH | INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS | SILTS AND CLAYS<br>LIQUID LIMIT GREATER THAN 50 | | | | | | |
| ▨ | CH | INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS | | | | | | | |
| ▨ | OH | ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS | | | | | | | |
| ▨ | PT | PEAT AND OTHER HIGHLY ORGANIC SOILS | HIGHLY ORGANIC SOILS | | | | | | |

# SOIL CLASSIFICATION CHART

## UNIFIED
## SOIL CLASSIFICATION SYSTEM

| SYMBOL | TYPE OF TEST |
|---|---|
| M | MOISTURE |
| QD | QUICK MD TEST BASED ON ASSUMED SPECIFIC GRAVITY |
| MD | MOISTURE-DENSITY |
| CD | CHUNK DENSITY ON BULK SAMPLE |
| RD | RELATIVE DENSITY |
| COMP | COMPACTION CURVE |
| CI | CALIFORNIA IMPACT |
| CC | COMPACTED CORE |
| G | SPECIFIC GRAVITY |
| pH | HYDROGEN ION CONCENTRATION |
| MA<br>(10%) | MECHANICAL ANALYSIS*<br>(INDICATES PERCENT PASSING #200 SIEVE) |
| SA<br>(10%) | SIEVE ANALYSIS (+200 ONLY)<br>(INDICATES PERCENT PASSING #200 SIEVE) |
| HA | HYDROMETER ANALYSIS (-200 ONLY) |
| AL | ATTERBERG LIMITS (LL & PL) |
| SL | SHRINKAGE LIMIT |
| FS | FREE SWELL |
| SS | SHRINK-SWELL |
| EXP | EXPANSION |
| C | CONSOLIDATION |
| VC | VIBRATING CONSOLIDATION |
| P | PERMEABILITY |
| UC | UNCONFINED COMPRESSION |
| | FRICTION TEST |
| F/UU | 1. UNCONSOLIDATED-UNDRAINED |
| F/CU | 2. CONSOLIDATED-UNDRAINED |
| F/CU/MΦ | 3. CU/MULTIPHASE** |
| F/CU/PP | 4. CU/WITH PORE PRESSURE MEASUREMENTS |
| F/CD | 5. CONSOLIDATED-DRAINED |
| | DIRECT SHEAR TEST |
| DS/UU | 1. UNSOLIDATED - UNDRAINED |
| DS/CU | 2. CONSOLIDATED-UNDRAINED |
| DS/CD | 3. CONSOLIDATED-DRAINED |
| DS/CD/MΦ | 4. CD/MULTIPHASE ** |
| LV | TORVANE SHEAR (LAB VANE SHEAR) |

* INCLUDES COMPLETE ANALYSIS, SIEVING AND HYDROMETER
** SERIES OF TESTS RUN ON SAMPLE



## PLASTICITY CHART

■ INDICATES DEPTH OF UNDISTURBED SAMPLE
☒ INDICATES DEPTH OF DISTURBED SAMPLE
☐ INDICATES DEPTH OF SAMPLING ATTEMPT WITH NO RECOVERY
◩ INDICATES DEPTH OF STANDARD PENETRATION TEST
⧄ INDICATES DEPTH OF STANDARD PENETRATION TEST WITH NO RECOVERY
I INDICATES DEPTH & LENGTH OF CORING RUN
⧗ INDICATES DEPTH OF FIELD VANE SHEAR TEST

NOTE:
UNLESS OTHERWISE NOTED SAMPLING RESISTANCE IS MEASURED IN BLOWS PER FOOT REQUIRED TO DRIVE SAMPLER 12-INCHES AFTER SAMPLER HAS BEEN SEATED 6-INCHES. THE WEIGHT & DROP OF THE DRIVING MECHANISM IS NOTED ON EACH LOG OF BORING.

## KEY TO SAMPLES

D - DAMES & MOORE, TYPE D SAMPLER
P - DAMES & MOORE PISTON SAMPLER
U - DAMES & MOORE TYPE U SAMPLER
PT - PITCHER TUBE SAMPLER
NX - NX CORE SAMPLER
TW - DAMES & MOORE TYPE U SAMPLER WITH THIN WALL ATTACHMENT
SPT - STANDARD PENETRATION TEST SAMPLER
ST - SHELBY TUBE SAMPLER

## KEY TO SAMPLERS

# SOIL CLASSIFICATION CHART AND KEY TO TEST DATA

**DAMES & MOORE**

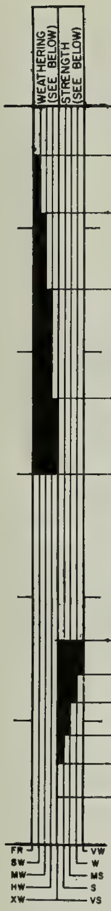
PLATE A-2A

## GRAPHIC LOG

|  |  |  |  |  |  |
|---|---|---|---|---|---|
| ▨ | SANDSTONE | ▨ | BEDDED CHERT | ▨ | SHALE |
| ▨ | GRAYWACKE | ▨ | GREENSTONE | ▨ | MELANGE |
| ▨ | SILTSTONE | ▨ | SERPENTINE | ▨ | BRECCIA - MAY APPLY TO ANY ROCK TYPE SHOWN ABOVE. |

## FRACTURE ORIENTATION

| | |
|---|---|
| ▨ | SHEAR ZONE |



## DEGREE OF WEATHERING

| ABBREVIATION | TERM | DESCRIPTION |
|---|---|---|
| FR | FRESH | THE ROCK SHOWS NO DISCOLORATION, LOSS OF STRENGTH OR ANY OTHER EFFECT DUE TO WEATHERING. |
| SW | SLIGHTLY WEATHERED | THE ROCK IS SLIGHTLY DISCOLORED, BUT NOT NOTICEABLY LOWER IN STRENGTH THAN THE FRESH ROCK. |
| MW | MODERATELY WEATHERED | THE ROCK IS DISCOLORED AND NOTICEABLY WEAKENED, BUT 2-INCH DIAMETER DRILL CORES CANNOT USUALLY BE BROKEN UP BY HAND, ACROSS THE ROCK FABRIC. |
| HW | HIGHLY WEATHERED | THE ROCK IS USUALLY DISCOLORED AND WEAKENED TO SUCH AN EXTENT THAT 2-INCH DIAMETER CORES CAN BE BROKEN UP READILY BY HAND ACROSS THE ROCK FABRIC. WET STRENGTH USUALLY MUCH LOWER THAN DRY STRENGTH. |
| XW | EXTREMELY WEATHERED | ROCK IS DISCOLORED AND IS ENTIRELY CHANGED TO A SOIL BUT THE ORIGINAL FABRIC OF THE ROCK IS MOSTLY PRESERVED. THE PROPERTIES OF THE SOIL DEPEND UPON THE COMPOSITION AND STRUCTURE OF THE PARENT ROCK. |

## STRENGTH

| ABBREVIATION | TERM | UNCONFINED COMPRESSIVE STRENGTH |
|---|---|---|
| VW | VERY WEAK | 1,000 PSI |
| W | WEAK | 1,000 - 3,000 PSI |
| MS | MODERATELY STRONG | 3,000 - 10,000 PSI |
| S | STRONG | 10,000 - 25,000 PSI |
| VS | VERY STRONG | 25,000 PSI |

## COMPRESSIVE STRENGTH BY POINT LOAD TESTS

CP = 14,200 PSI-D (DIAMETRAL TEST)
-A (AXIAL TEST)

## BEDDING CHARACTERISTICS

| AVERAGE BED THICKNESS | TERM |
|---|---|
| 0.001 FOOT | THINLY LAMINATED |
| 0.001 TO 0.01 FOOT | LAMINATED |
| 0.01 TO 0.1 FOOT | THIN BEDDED |
| 0.1 TO 1.0 FOOT | MEDIUM BEDDED |
| 1.0 FOOT | THICK BEDDED |

## CORE RECOVERY (%) :

THE HORIZONTAL LINES SHOW THE LENGTH OF EACH CORE RUN. THE NUMBER REPRESENTS THE AMOUNT OF CORE RECOVERED IN EACH RUN EXPRESSED AS A PERCENTAGE OF THE TOTAL LENGTH OF THE CORE RUN.

## ROCK QUALITY DESIGNATION (RQD) :

A MODIFIED CORE RECOVERY PERCENTAGE IN WHICH ONLY THE PIECES OF SOUND CORE OVER 4-INCHES LONG ARE COUNTED AS RECOVERY. THE MODIFIED SUM OF CORE RECOVERED IS EXPRESSED AS A PERCENTAGE OF THE TOTAL LENGTH OF THE CORE RUN.

## NOTE:

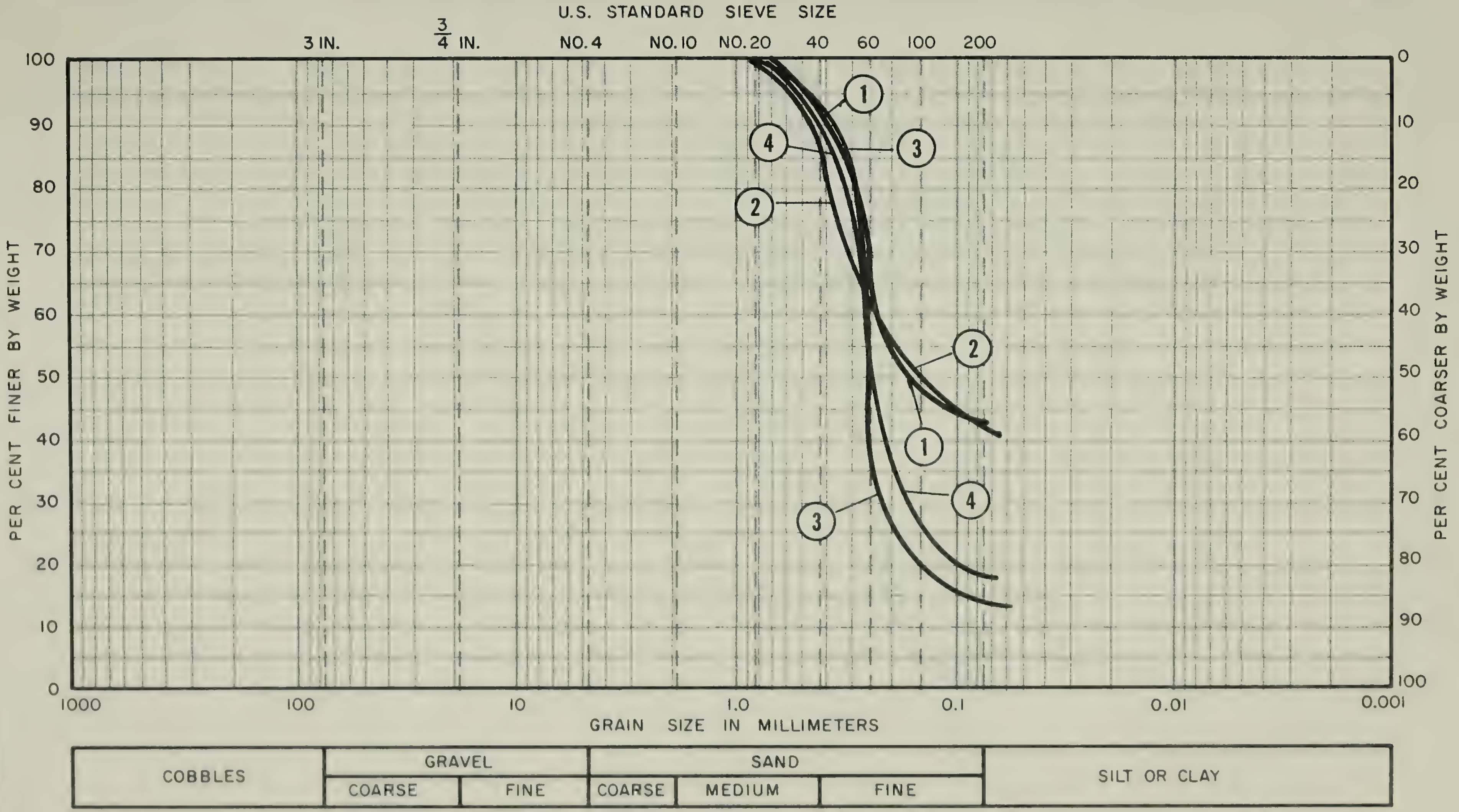
THE DISCUSSION IN THE TEXT OF THE REPORT IS NECESSARY FOR A PROPER UNDERSTANDING OF THE NATURE OF THE SUBSURFACE MATERIALS.

# ROCK CLASSIFICATION CHART AND KEY TO GEOLOGIC LOGS

**DAMES & MOORE**

PLATE A-2B

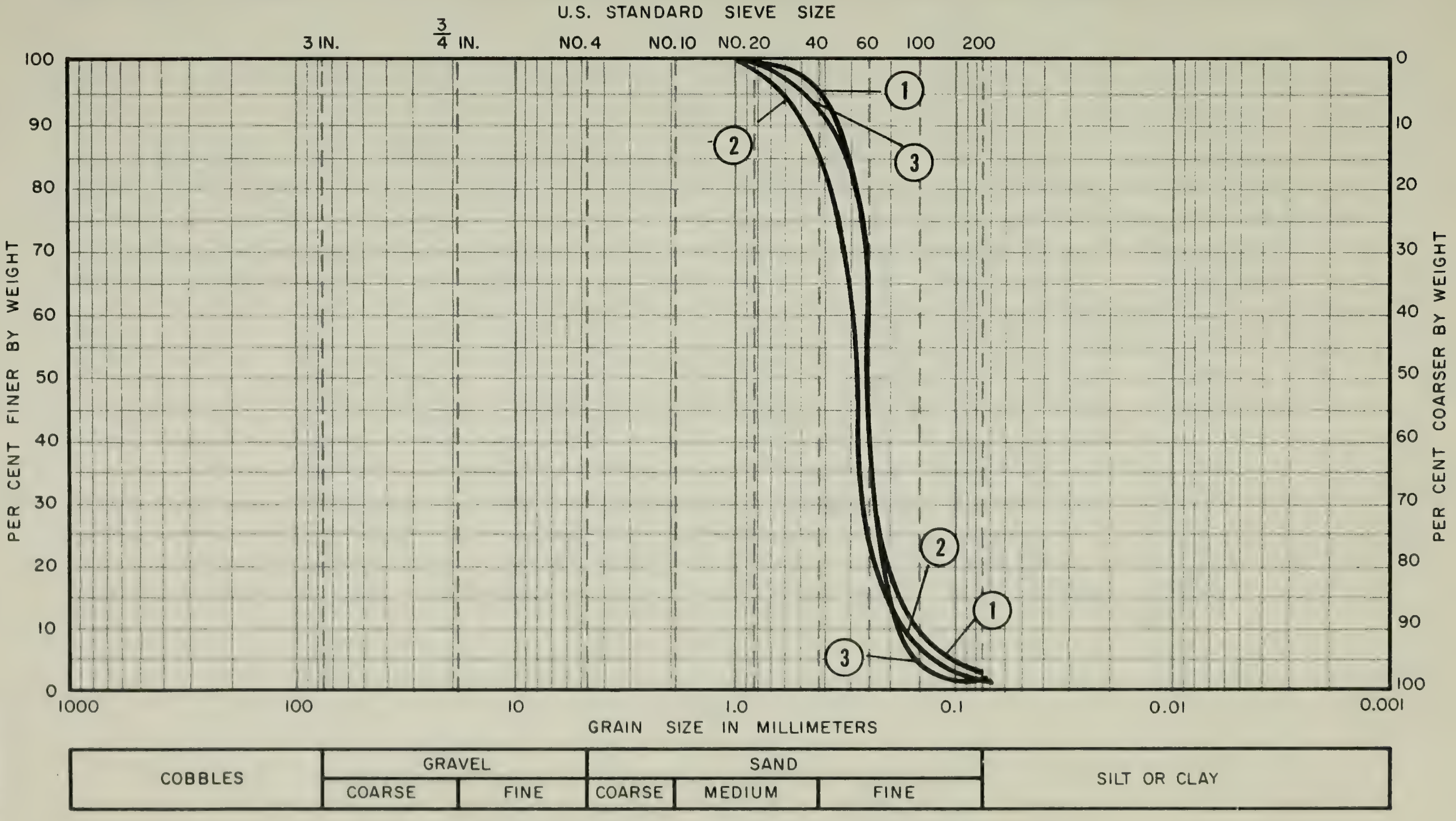
| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 2 | 11.3 | +48.7 | 3 | COLMA | | SM | DARK BROWN SILTY FINE SAND | ① |
| 2 | 20.5 | +39.5 | 7 | COLMA | | SM | BROWN SILTY FINE SAND | ② |
| 2 | 35.5 | +24.5 | 13 | COLMA | | SM | BROWN SILTY FINE SAND | ③ |
| 3 | 120 | +22.0 | 22 | COLMA | 2x10$^{-7}$ | SM | BROWN SILTY SAND | ④ |



GRAIN-SIZE DISTRIBUTION
(unified soil classification system)

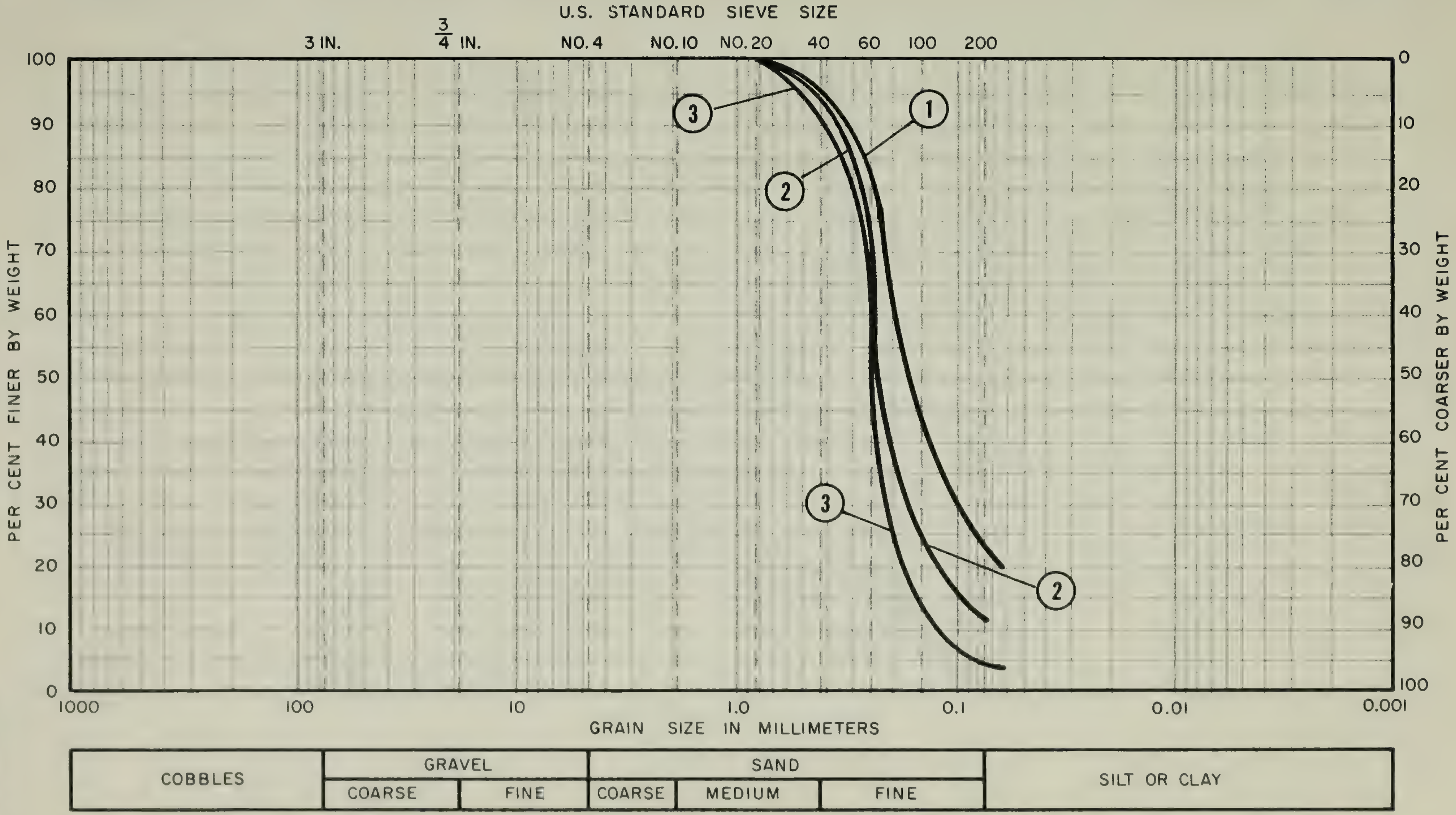
DAMES & MOORE

| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 5 | 39 | +31.5 | 9 | DUNE | $2x10^{-3}$ | SP | BROWN FINE SAND | ① |
| 7 | 15.5 | +131.5 | 2 | DUNE |  | SP | BROWN-GRAY FINE SAND | ② |
| 7 | 45.5 | +101.5 | 5 | DUNE |  | SP | BROWN FINE SAND | ③ |
|  |  |  |  |  |  |  |  |  |



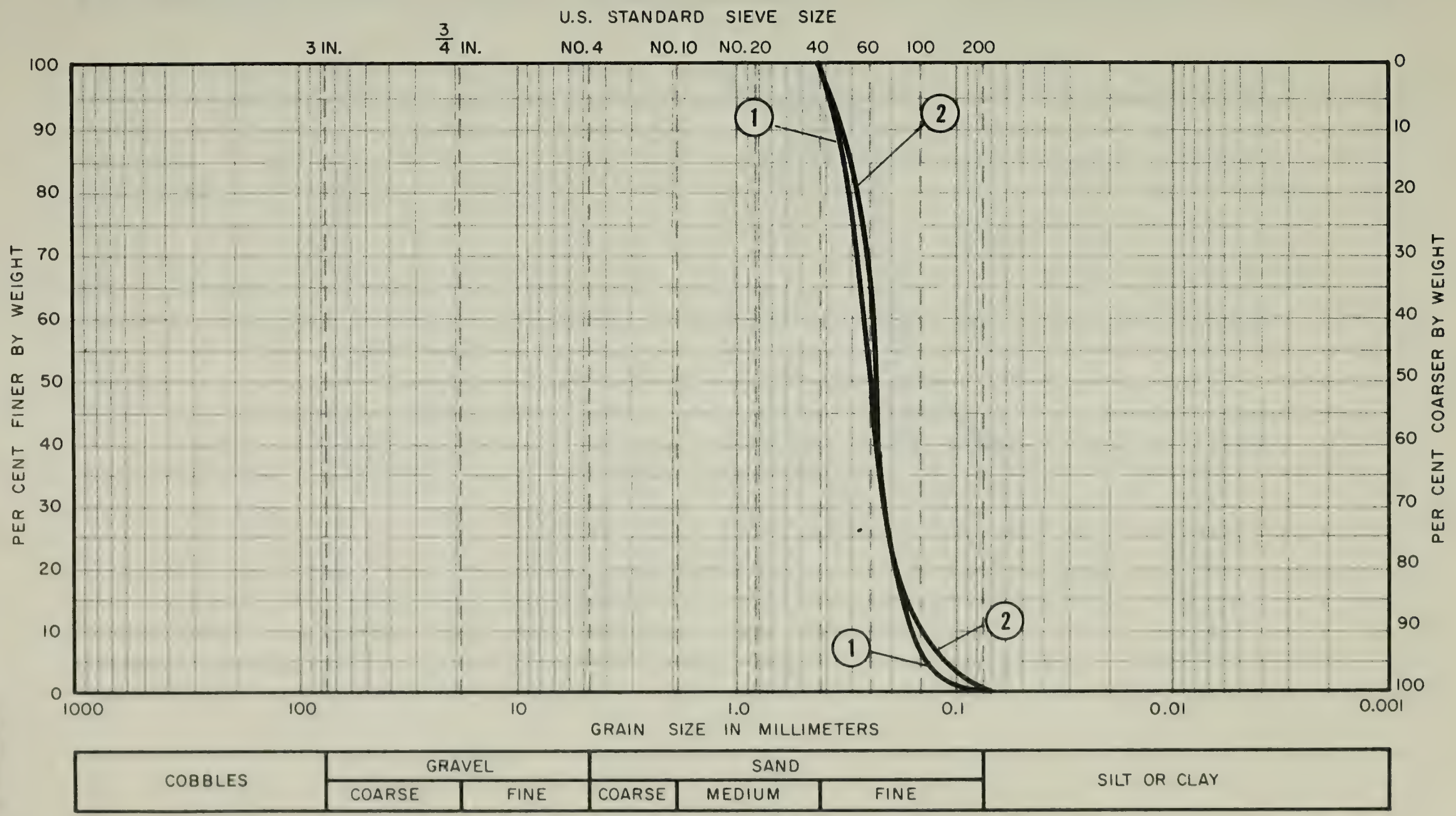
# GRAIN-SIZE DISTRIBUTION
## (unified soil classification system)

| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 7 | 75.5 | +71.5 | 9 | COLMA |  | SM | TAN SILTY FINE SAND | ① |
| 7 | 85.0 | +62.0 | 10 | COLMA | 2x10$^{-6}$ | SP | BROWN SILTY FINE SAND | ② |
| 7 | 155.5 | -8.5 | 22 | COLMA |  | SP | DARK BROWN FINE SAND | ③ |
|  |  |  |  |  |  |  |  |  |



# GRAIN-SIZE DISTRIBUTION
(unified soil classification system)

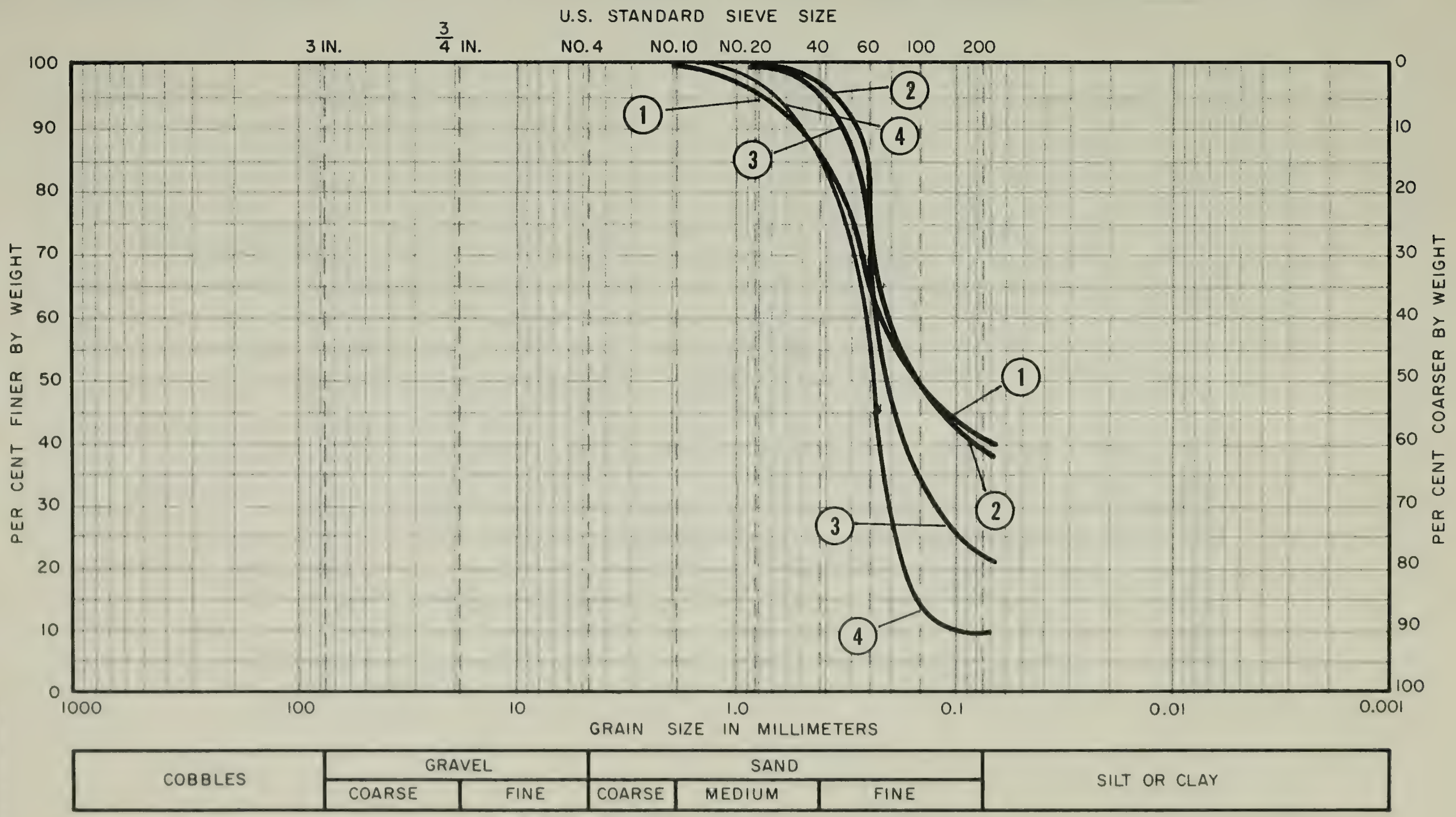
| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 8 | 14.5 | +13.5 | 7 | DUNE | | SP | BROWN FINE SAND | ① |
| 8 | 40 | -12.0 | 15 | DUNE | | SP | BROWN FINE SAND | ② |
| | | | | | | | | |
| | | | | | | | | |



# GRAIN-SIZE DISTRIBUTION
## (unified soil classification system)

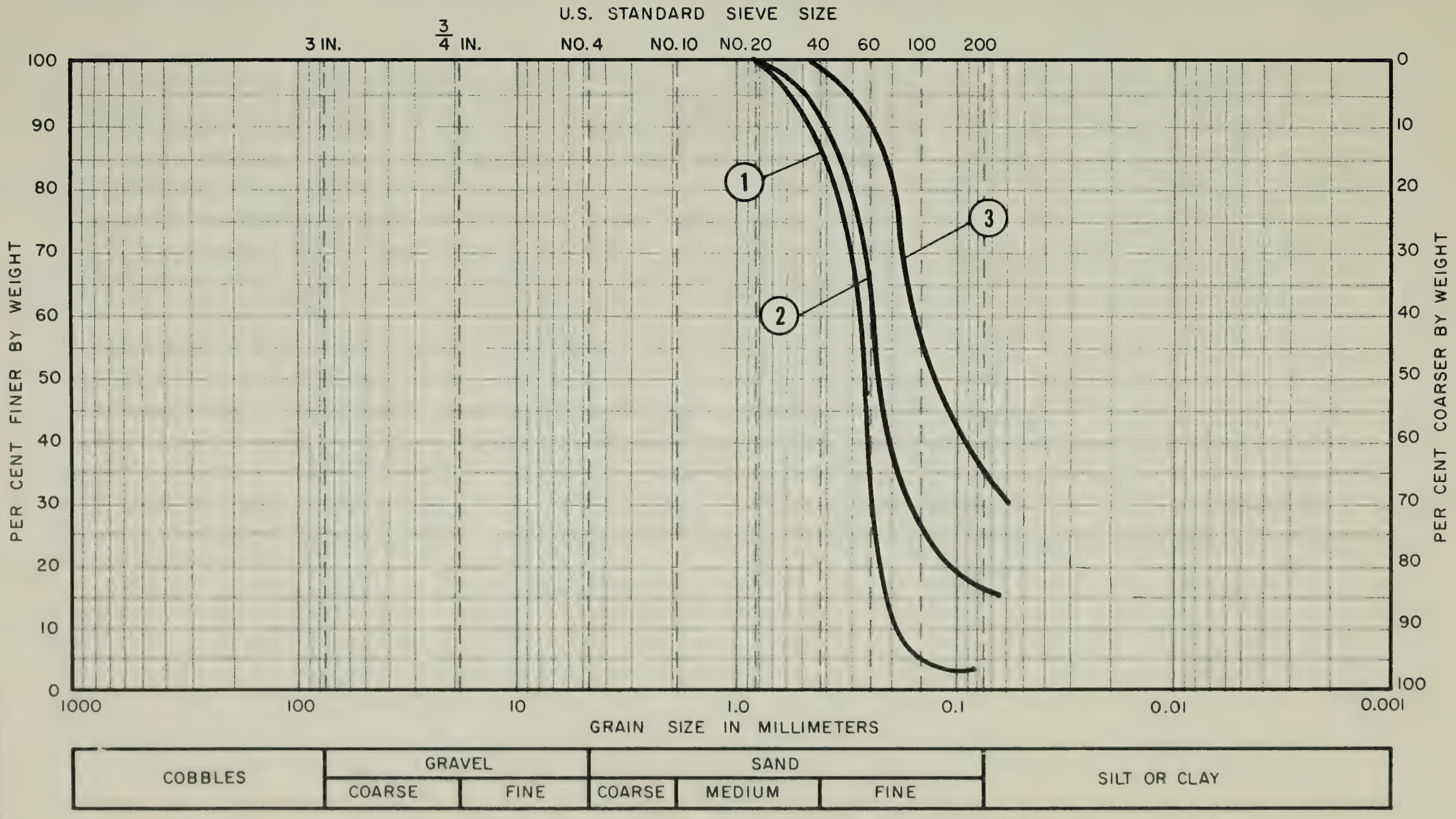
**DAMES & MOORE**

| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 9 | 41.3 | +119.7 | 4 | COLMA | | SM/SC | YELLOW/BRN CLAYEY SILTY SAND | ① |
| 9 | 101.4 | +59.6 | 10 | COLMA | | SM | TAN SILTY FINE SAND | ② |
| 9 | 136.5 | +24.5 | 18 | COLMA | | SM | BROWN SILTY FINE SAND | ③ |
| 9 | 146 | +15.0 | 22 | COLMA | $2 \times 10^{-5}$ | SP | BROWN FINE MEDIUM SAND | ④ |



# GRAIN-SIZE DISTRIBUTION
## (unified soil classification system)

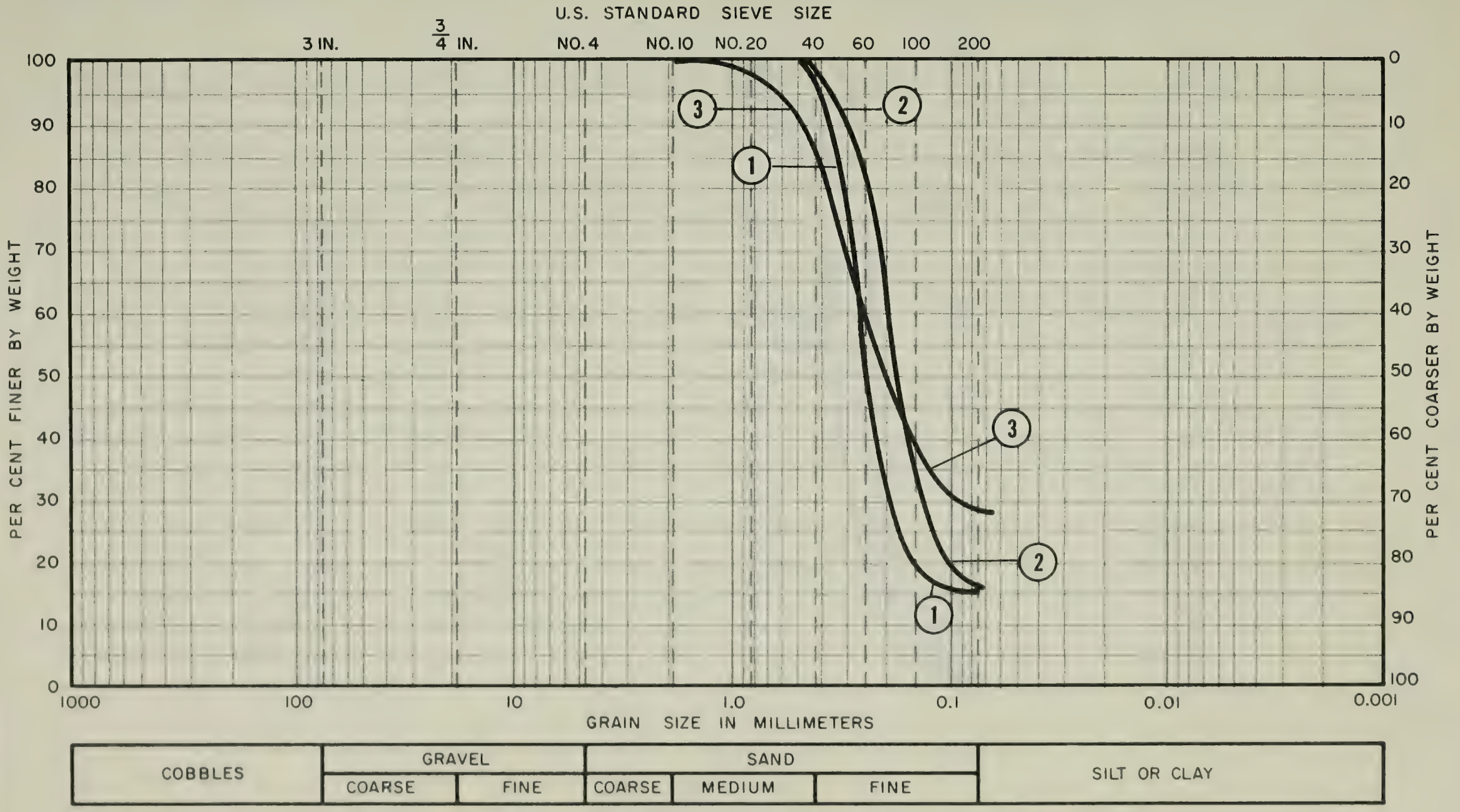
| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 10 | 35 | +36.0 | 3 | DUNE | $4 \times 10^{-3}$ | SP | BROWN FINE SAND | ① |
| 10 | 85 | -14.0 | 15 | COLMA | | SM | BROWN SILTY SAND | ② |
| 10 | 90 | -19.0 | 16 | COLMA | | SM | BROWN SILTY FINE SAND | ③ |
| | | | | | | | | |



# GRAIN-SIZE DISTRIBUTION
(unified soil classification system)

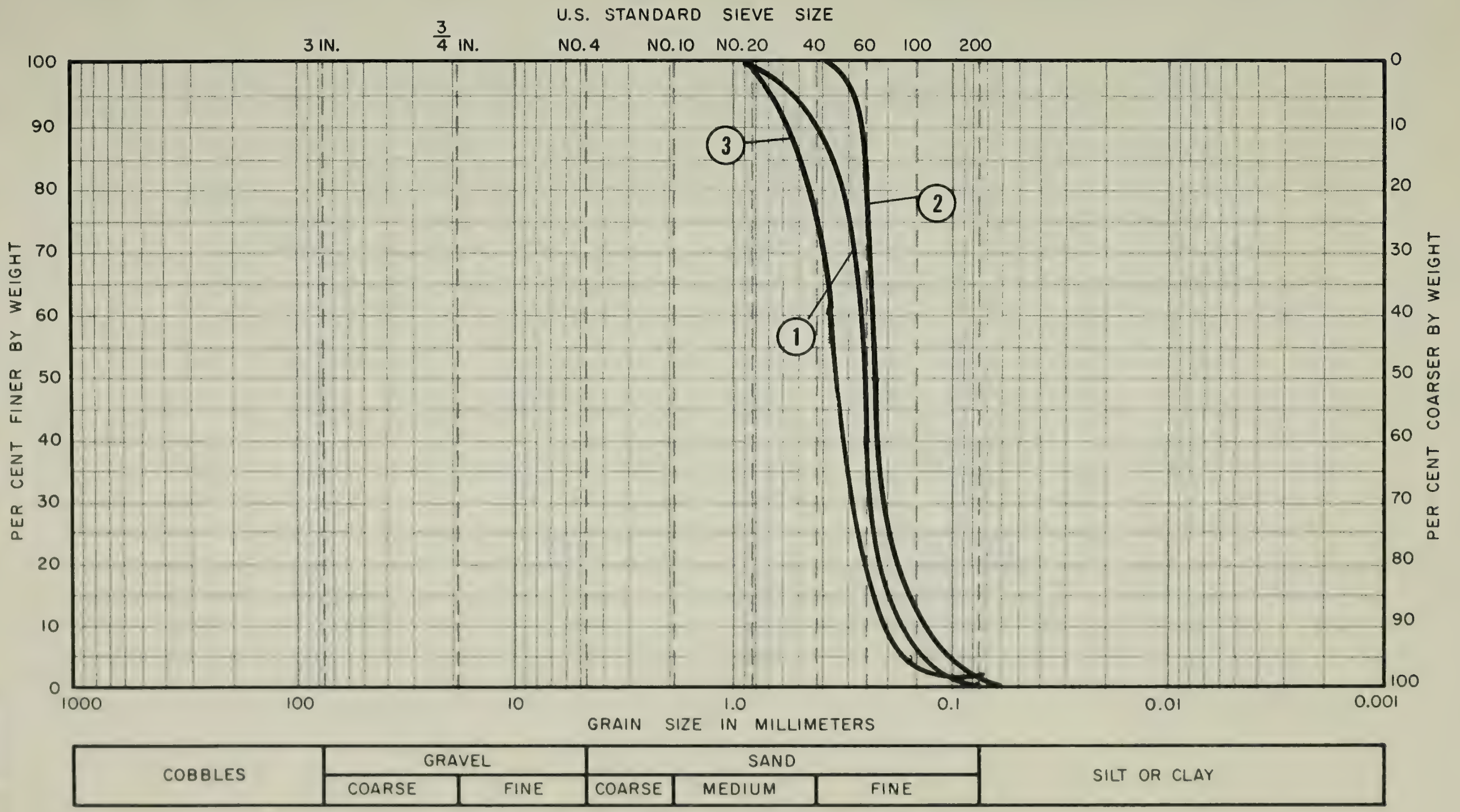
**DAMES & MOORE**

| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 11 | 35 | +98.0 | 5 | COLMA |  | SM/SP | BROWN FINE SAND | ① |
| 11 | 65.5 | +67.5 | 7 | COLMA |  | SM | BROWN SILTY FINE SAND | ② |
| 11 | 106 | +27.0 | 15 | COLMA |  | SM | RUST BROWN SILTY FINE SAND | ③ |
|  |  |  |  |  |  |  |  |  |



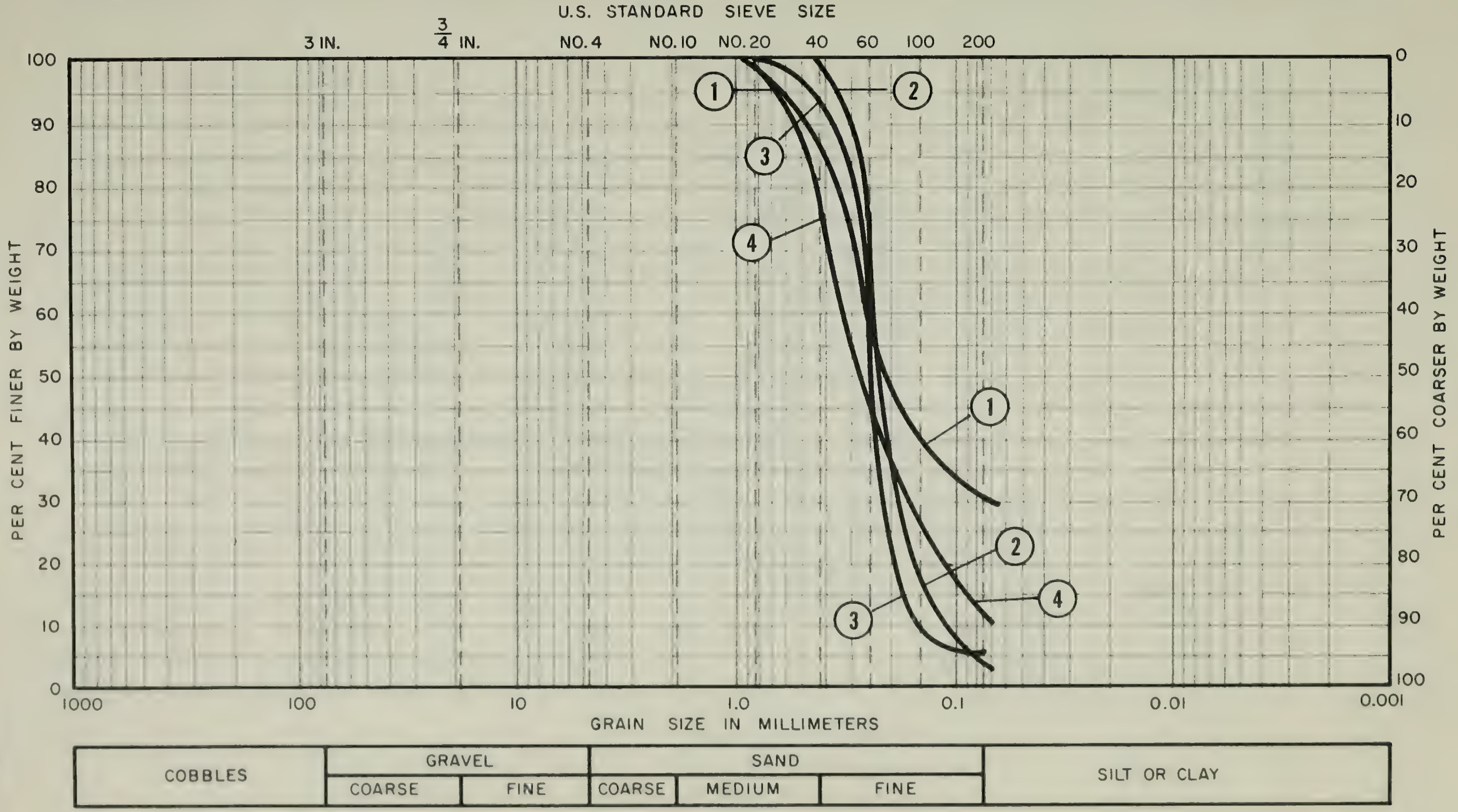
## GRAIN-SIZE DISTRIBUTION
(unified soil classification system)

| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 12 | 15.5 | +126.0 | 2 | DUNE | | SP | BROWN FINE SAND | ① |
| 12 | 45.5 | +96.0 | 5 | DUNE | | SP | BROWN FINE SAND | ② |
| 12 | 120 | +21.5 | 26 | COLMA | $7\text{x}10^{-4}$ | SP | BROWN FINE MEDIUM SAND | ③ |
| | | | | | | | | |



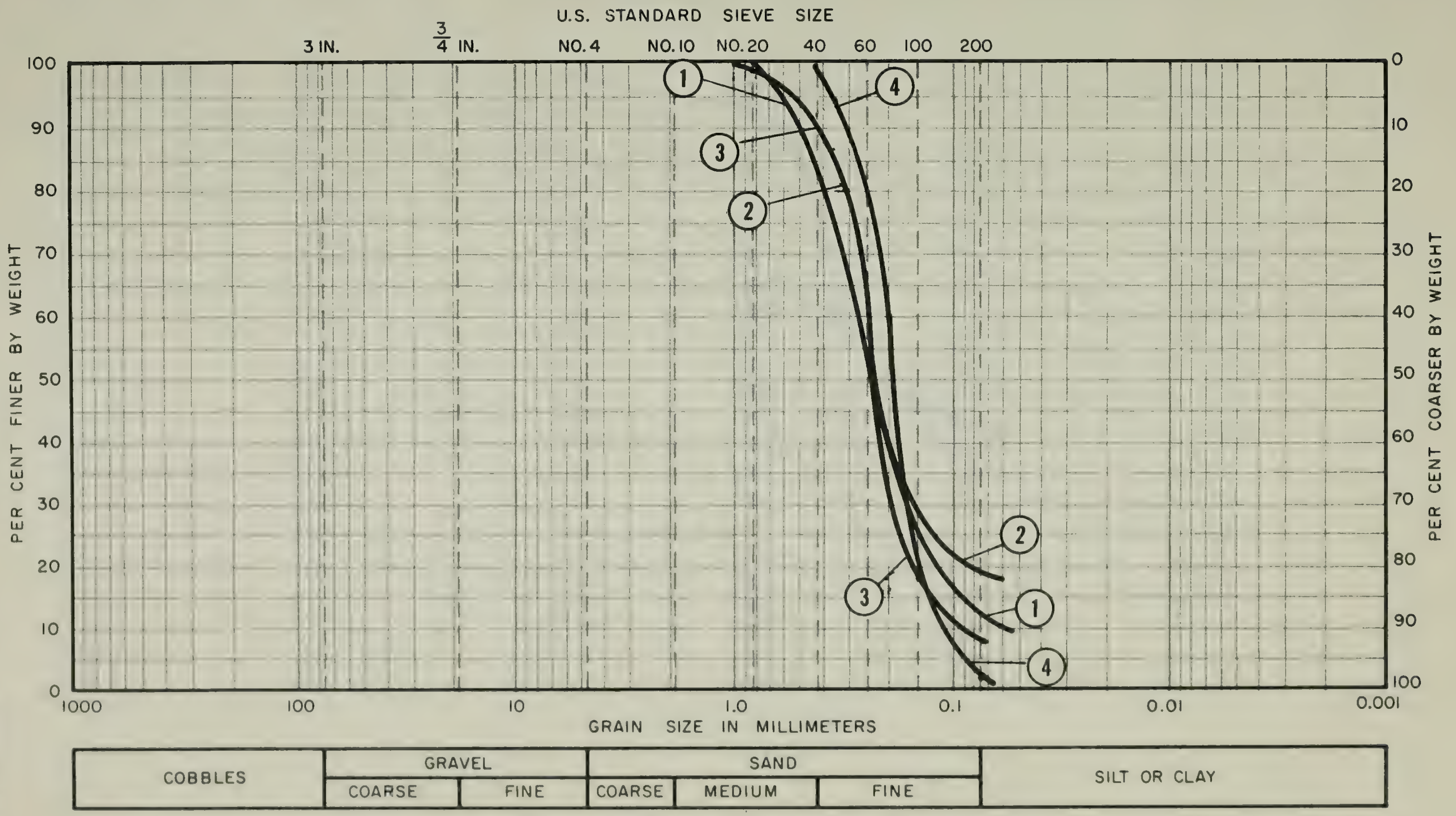
# GRAIN-SIZE DISTRIBUTION
(unified soil classification system)

| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 12 | 76.4 | +65.1 | 8 | COLMA | | SM | GRAY SILTY FINE SAND | ① |
| 12 | 130.9 | +10.6 | 30 | COLMA | | SP | YELLOW BROWN FINE SAND | ② |
| 12 | 175.6 | -34.1 | 40 | COLMA | | SP | BROWN FINE SAND | ③ |
| 14 | 96 | +15.2 | 16 | COLMA | $1x10^{-6}$ | SP/SM | BROWN SILTY SAND | ④ |



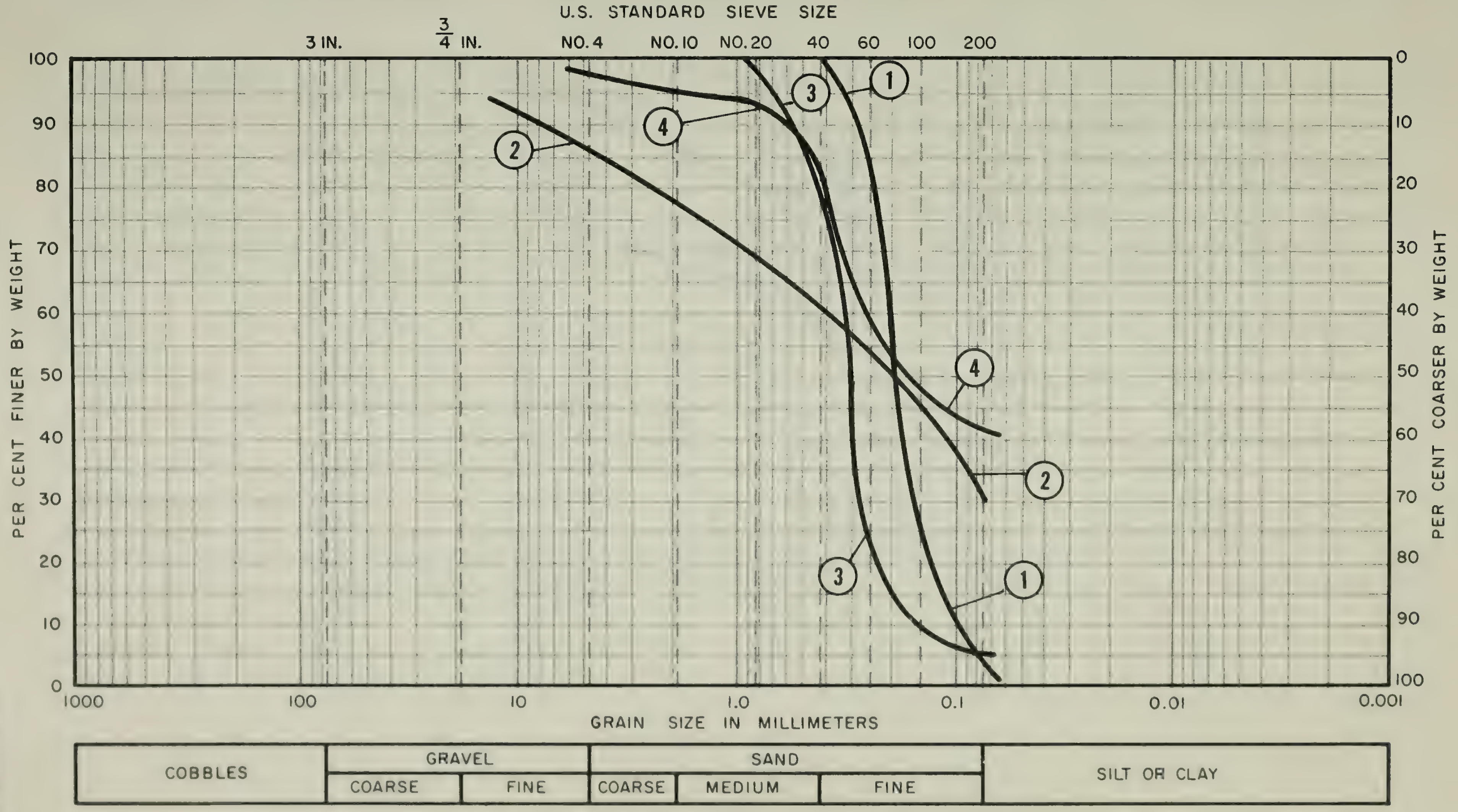
# GRAIN-SIZE DISTRIBUTION
(unified soil classification system)

| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 14 | 96.3 | +15.2 | 16 | COLMA | $1x10^{-6}$ | SM/SP | GRAY BROWN FINE SAND | ① |
| 16 | 91.5 | +99.5 | 9 | COLMA |  | SM | BROWN SILTY FINE SAND | ② |
| 16 | 161.4 | +29.6 | 22 | COLMA |  | SP | BROWN FINE SAND | ③ |
| 16 | 176 | +15.0 | 28 | COLMA | $2x10^{-3}$ | SP | BROWN FINE SAND | ④ |



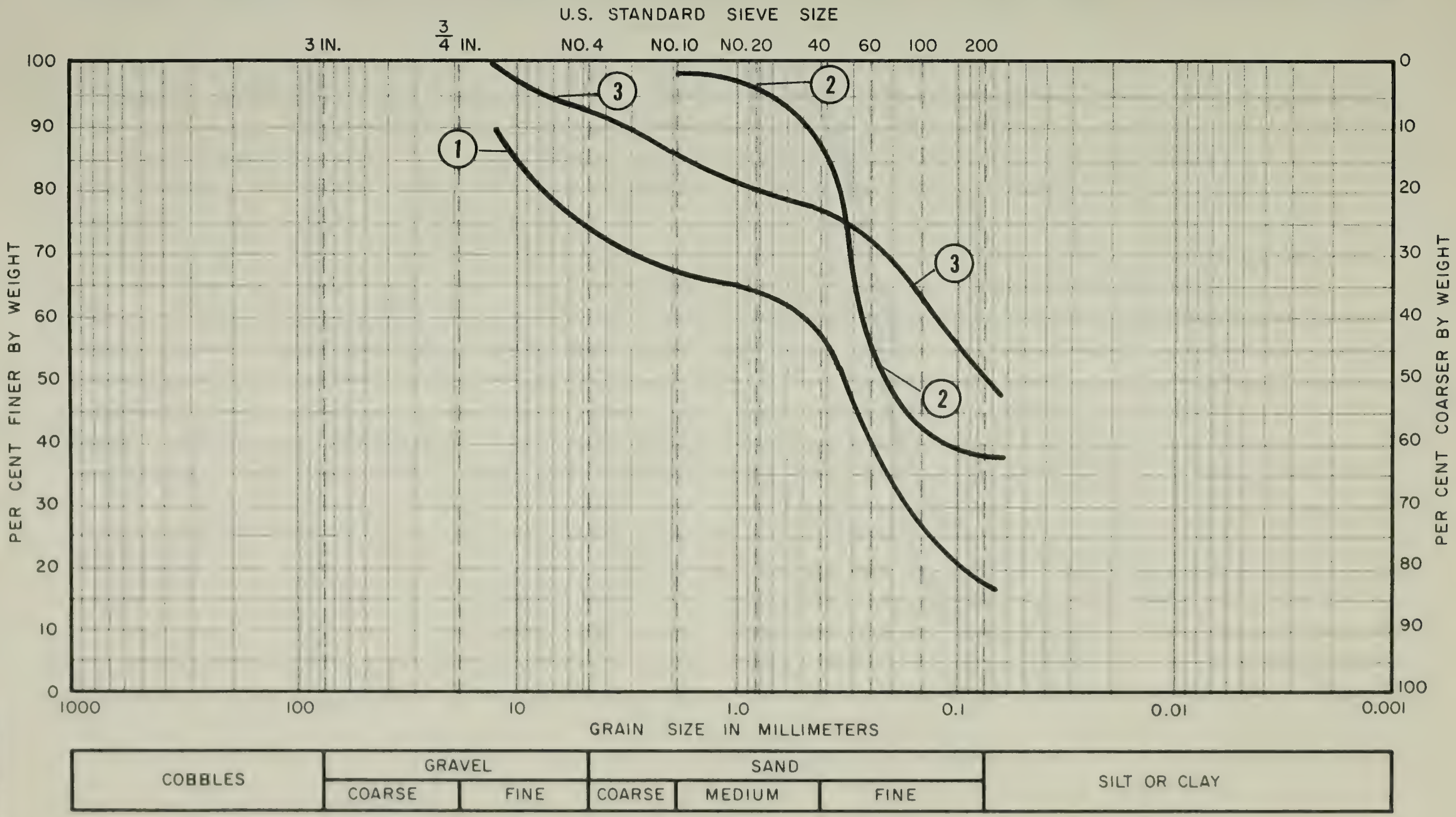
# GRAIN-SIZE DISTRIBUTION
## (unified soil classification system)

| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 18 | 130.7 | +61.3 | 13 | COLMA | | SP | BROWN FINE SAND | ① |
| 18 | 160.3 | +31.7 | 16 | COLLUVIUM | | GM | RUST BROWN GRAVELY SANDY SILT | ② |
| 18 | 170.2 | +21.8 | 17 | COLMA | | SP | BROWN FINE SAND | ③ |
| 18 | 171 | +21.0 | 18 | COLLUVIUM | | GC | YELLOW BROWN GRAVELY SANDY CLAY | ④ |



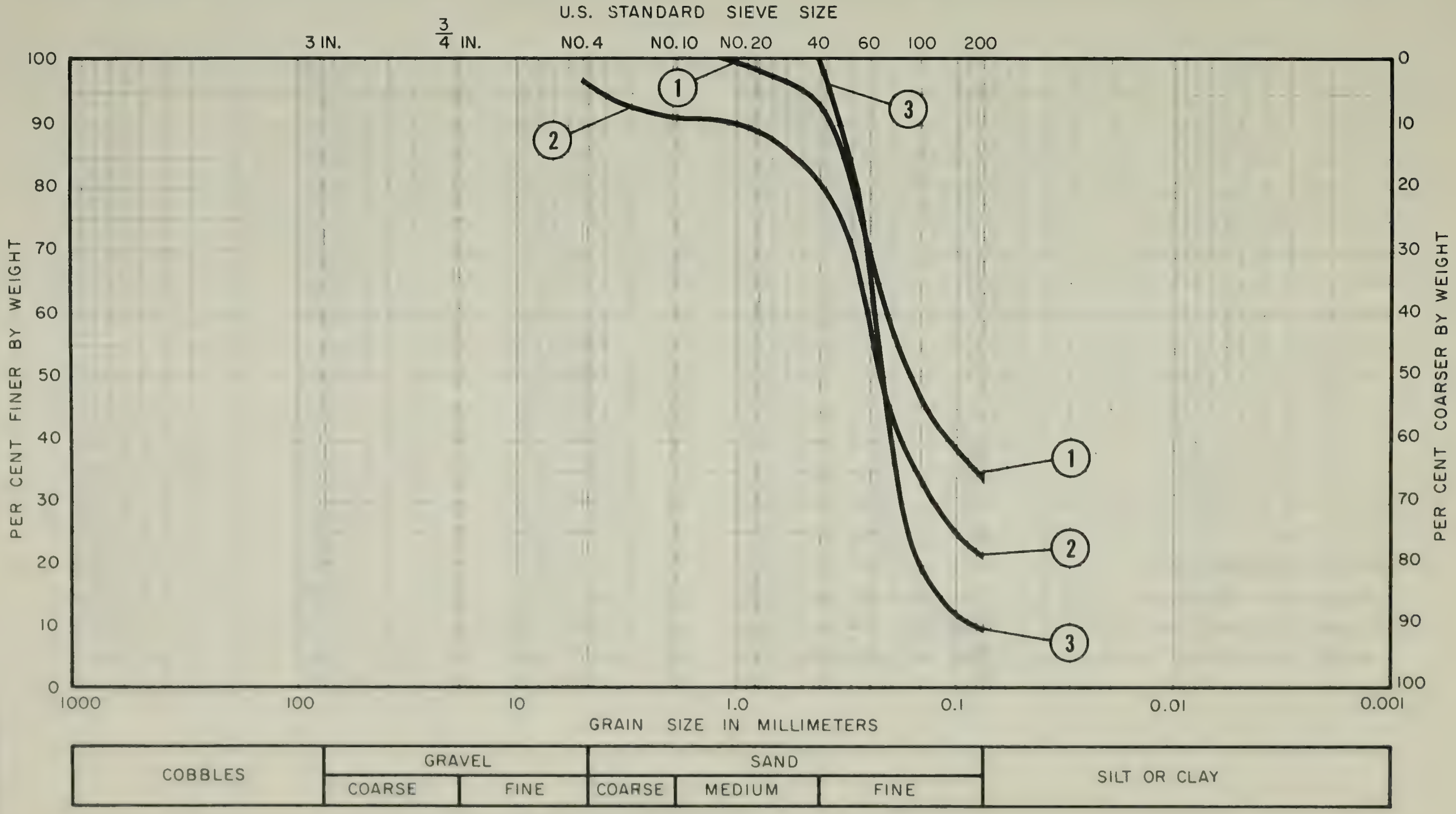
# GRAIN-SIZE DISTRIBUTION
## (unified soil classification system)

| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 18 | 175.3 | +16.7 | 19 | COLLUVIUM | | SM | BROWN GRAVELY SILTY SAND | ① |
| 18 | 180.6 | +11.4 | 21 | COLLUVIUM | | SM/SC | BROWN SILTY CLAYEY FINE SAND | ② |
| 18 | 186.2 | +5.8 | 23 | RESIDUAL | | CL | RUST BROWN SANDY CLAY W/ GRAVEL | ③ |
| | | | | | | | | |



## GRAIN-SIZE DISTRIBUTION
## (unified soil classification system)

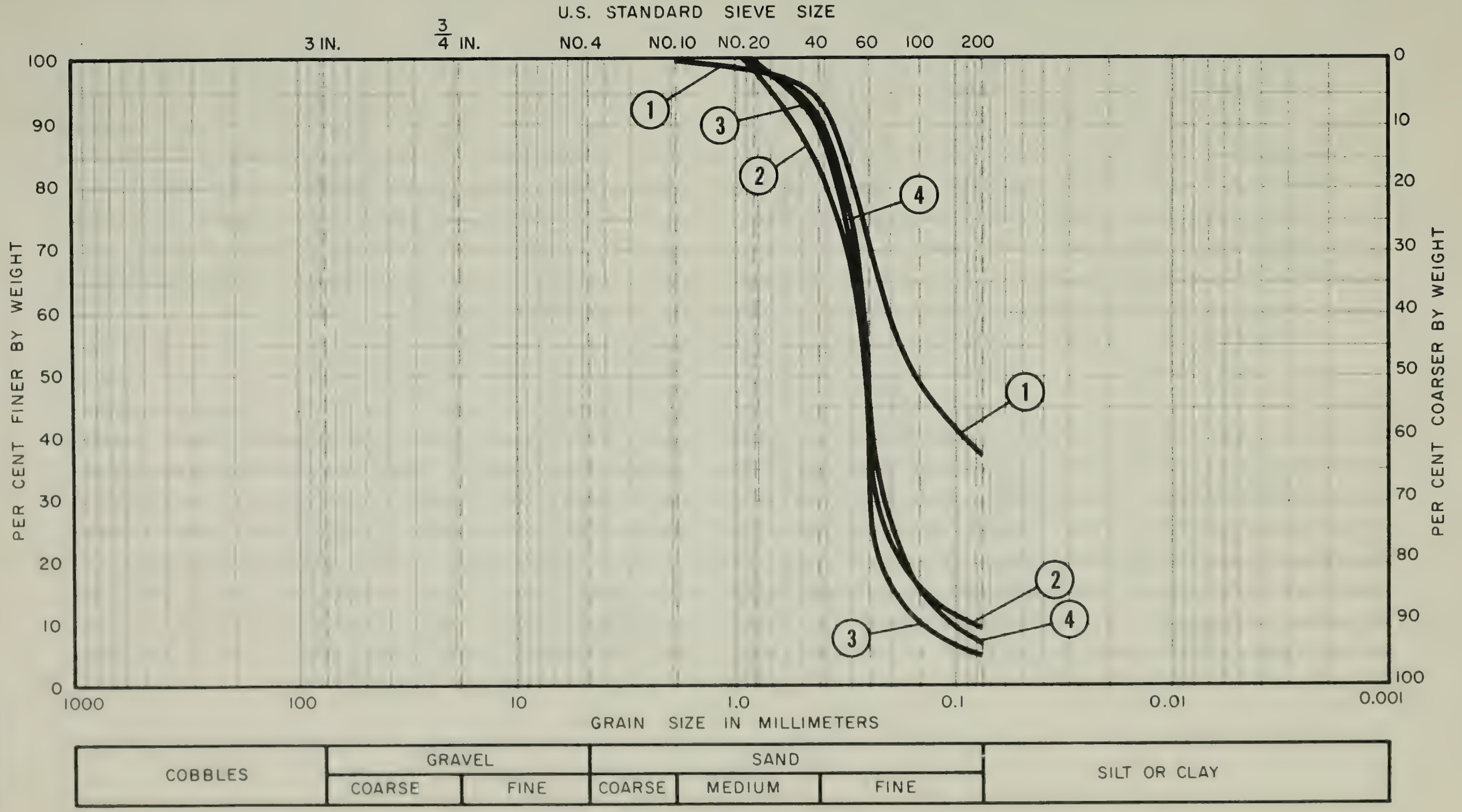
| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY | |
|---|---|---|---|---|---|---|---|---|---|
| 20 | 27 | +213 | 3 | COLMA | $1\text{x}10^{-6}$ | SM | GRAY-BROWN SILTY FINE SAND | ① | 1 |
| 20 | 41 | +199 | 4 | COLMA | $1\text{x}10^{-7}$ | SM | RED-BROWN SILTY MEDIUM FINE SAND | ② | 2 |
| 20 | 61 | +179 | 5 | COLMA | | SP/SM | BROWN SLIGHTLY SILTY FINE SAND | ③ | 3 |
| | | | | | | | | | |



# GRAIN-SIZE DISTRIBUTION
(unified soil classification system)

**DAMES & MOORE**

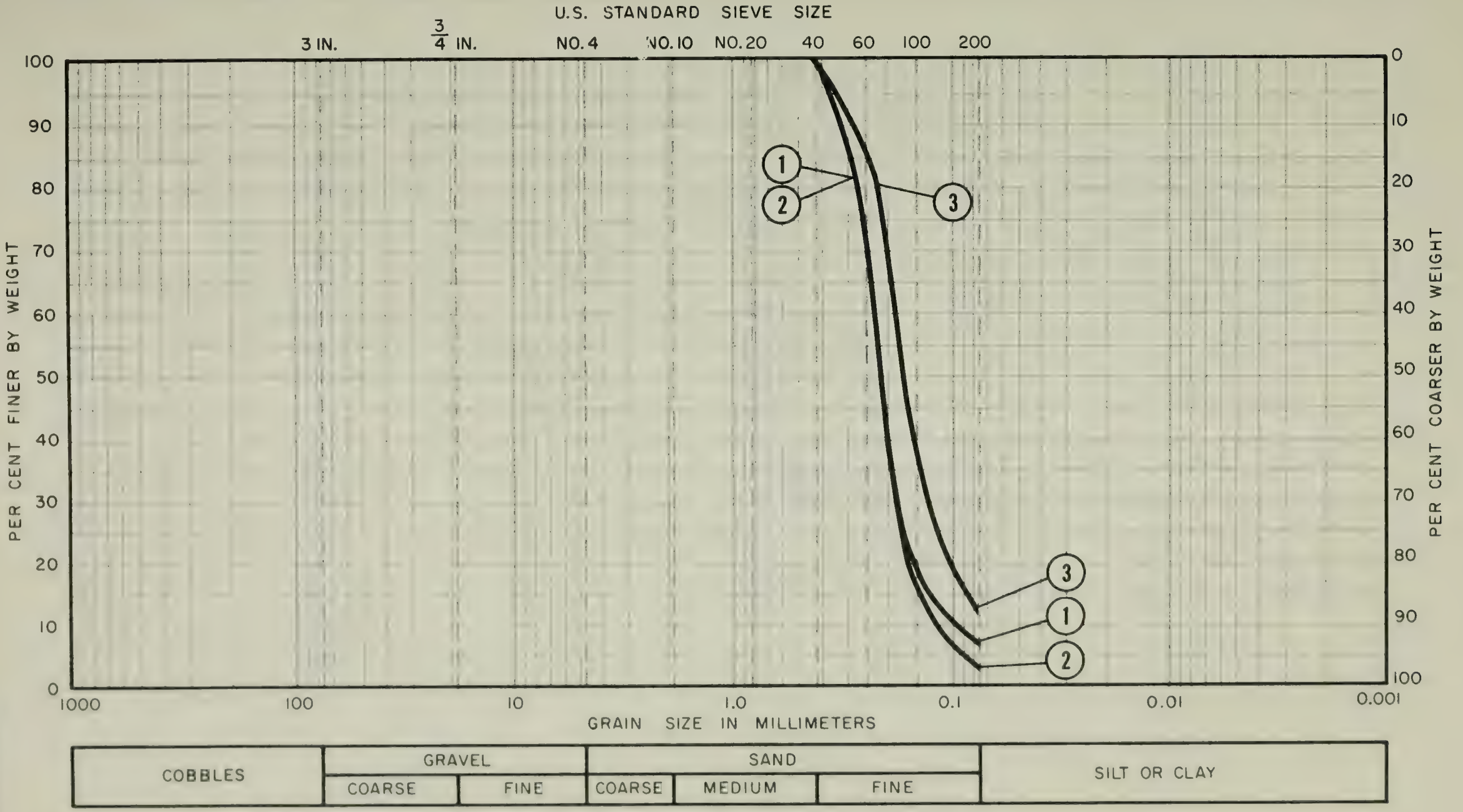
| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 21 | 30.5 | +164.5 | 4 | COLMA | | SM | LIGHT BROWN SILTY FINE SAND | ① |
| 21 | 40.1 | +155.0 | 5 | COLMA | | SP/SM | BROWN SLIGHTLY SILTY FINE SAND | ② |
| 21 | 50.4 | +144.6 | 6 | COLMA | | SP | BROWN FINE SAND | ③ |
| 21 | 70.5 | +124.5 | 8 | COLMA | | SP | BROWN FINE SAND | ④ |



# GRAIN-SIZE DISTRIBUTION
## (unified soil classification system)

**DAMES & MOORE**

| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 21 | 100.4 | +94.6 | 11 | COLMA | | SP | DARK BROWN FINE SAND | ① |
| 21 | 110.4 | +84.6 | 12 | COLMA | | SP | GRAY BROWN FINE SAND | ② |
| 21 | 120.4 | +74.6 | 13 | COLMA | | SP/SM | DARK BROWN SLIGHTLY SILTY FINE SAND | ③ |
| | | | | | | | | |

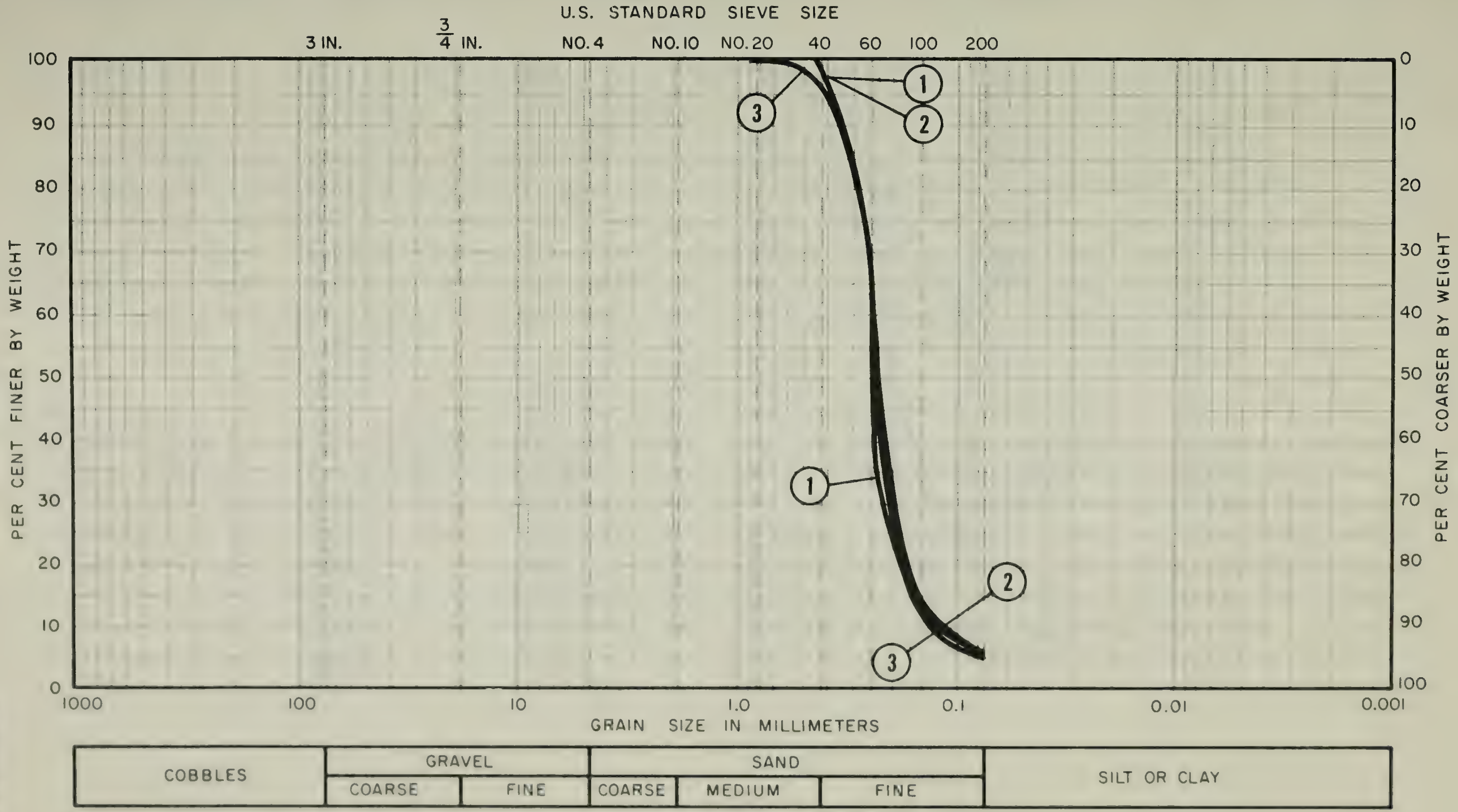


# GRAIN-SIZE DISTRIBUTION
## (unified soil classification system)

**DAMES & MOORE**

PLATE A-30

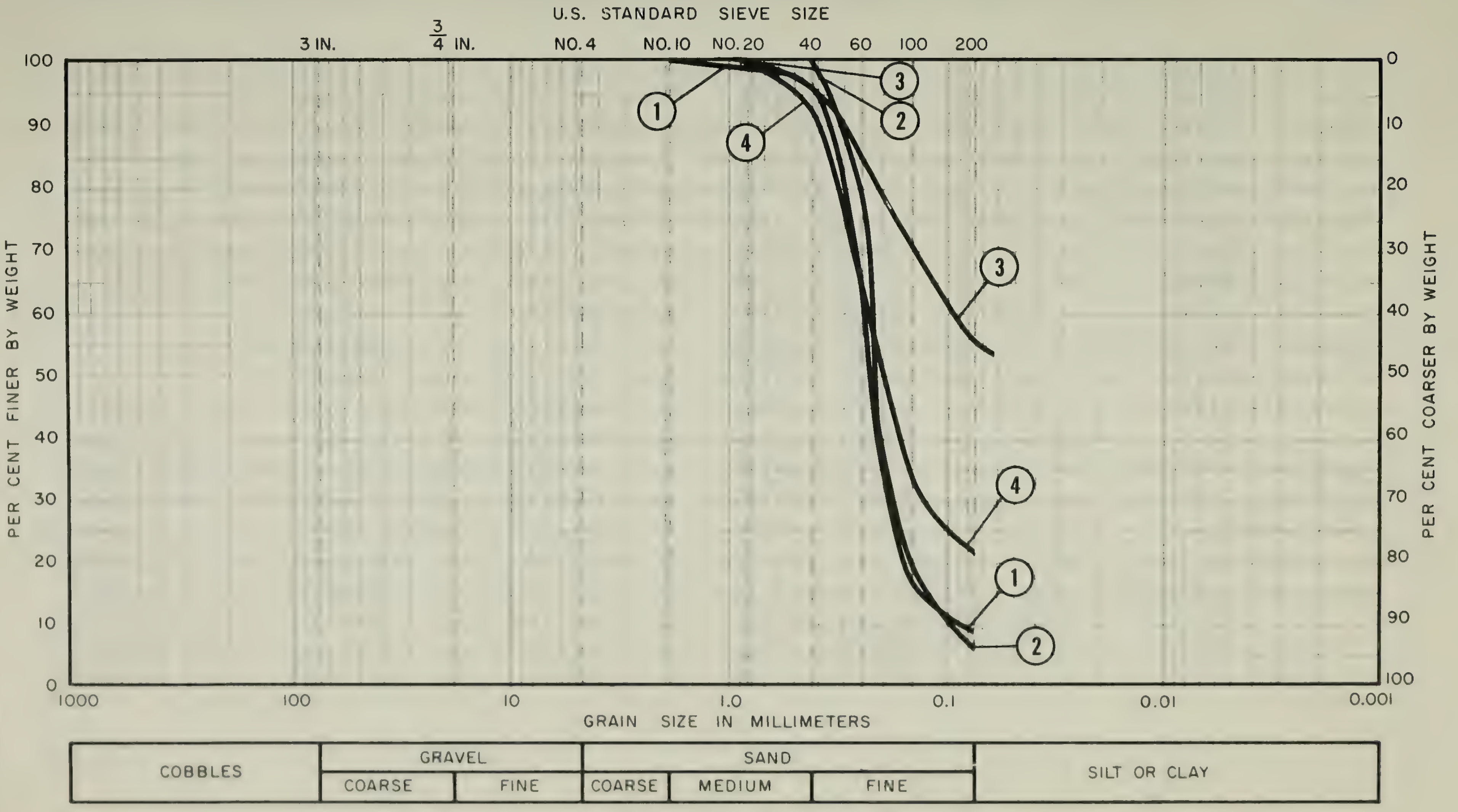
| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 21 | 125.3 | +69.7 | 14 | COLMA | $2\times10^{-4}$ | SP | GRAY-BROWN FINE SAND | ① |
| 21 | 130.2 | +64.8 | 15A | COLMA |  | SP | GRAY-BROWN FINE SAND | ② |
| 21 | 130.6 | +64.4 | 15B | COLMA |  | SP | GRAY-BROWN FINE SAND | ③ |
|  |  |  |  |  |  |  |  |  |



## GRAIN-SIZE DISTRIBUTION
(unified soil classification system)

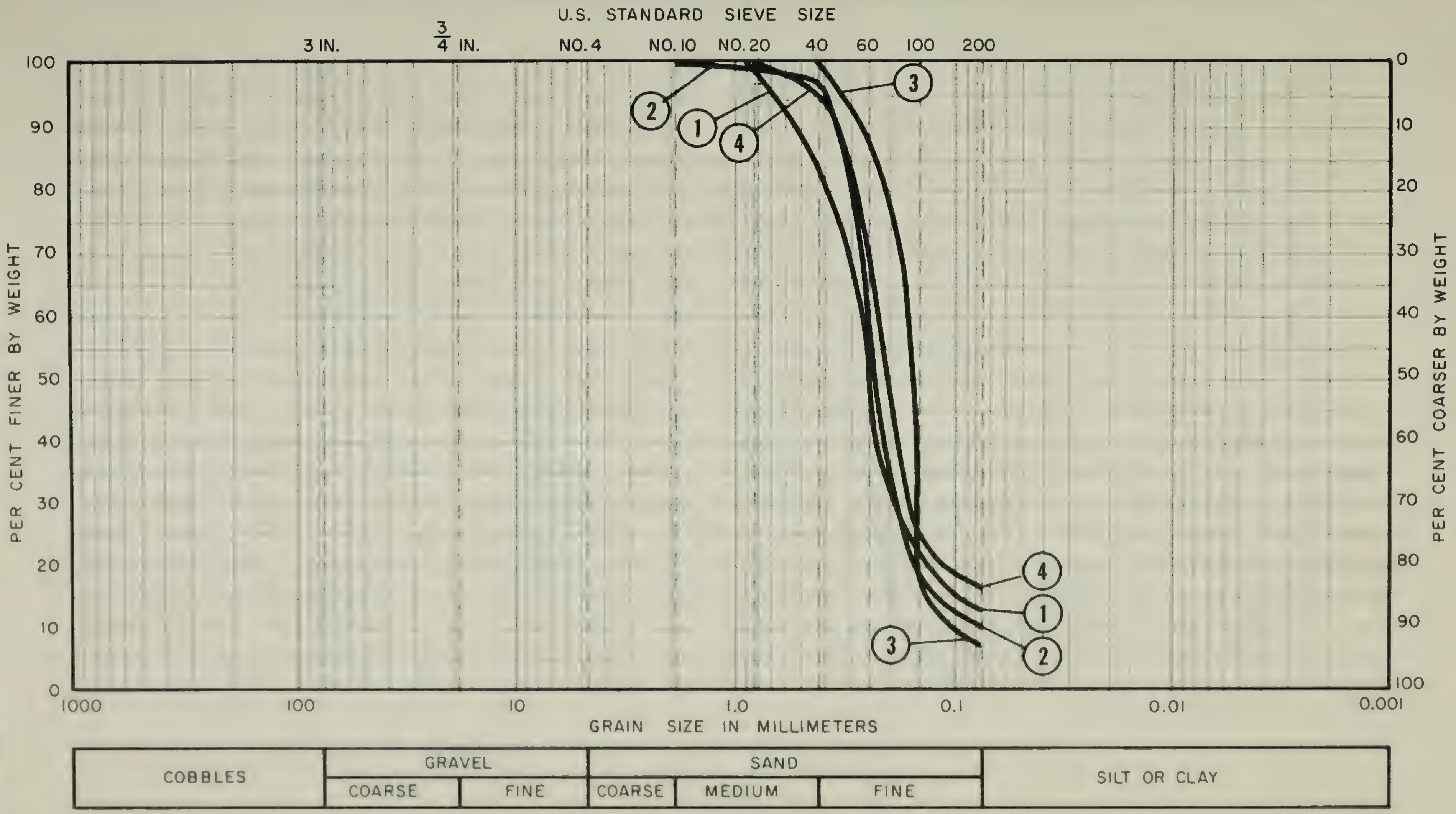
**DAMES & MOORE**

| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 21 | 135.5 | +59.5 | 16 | COLMA | | SP | GRAY-BROWN FINE SAND | ① |
| 21 | 140.2 | +54.8 | 17 | COLMA | $2\times10^{-4}$ | SP | RED-BROWN FINE SAND | ② |
| 21 | 165.3 | +29.7 | 22 | RESIDUAL | | CL | RED-BROWN & GRAY SANDY SILTY CLAY | ③ |
| 22 | 83.0 | +192.0 | 7 | COLMA | $2\times10^{-4}$ | SM | BROWN SILTY FINE SAND | ④ |



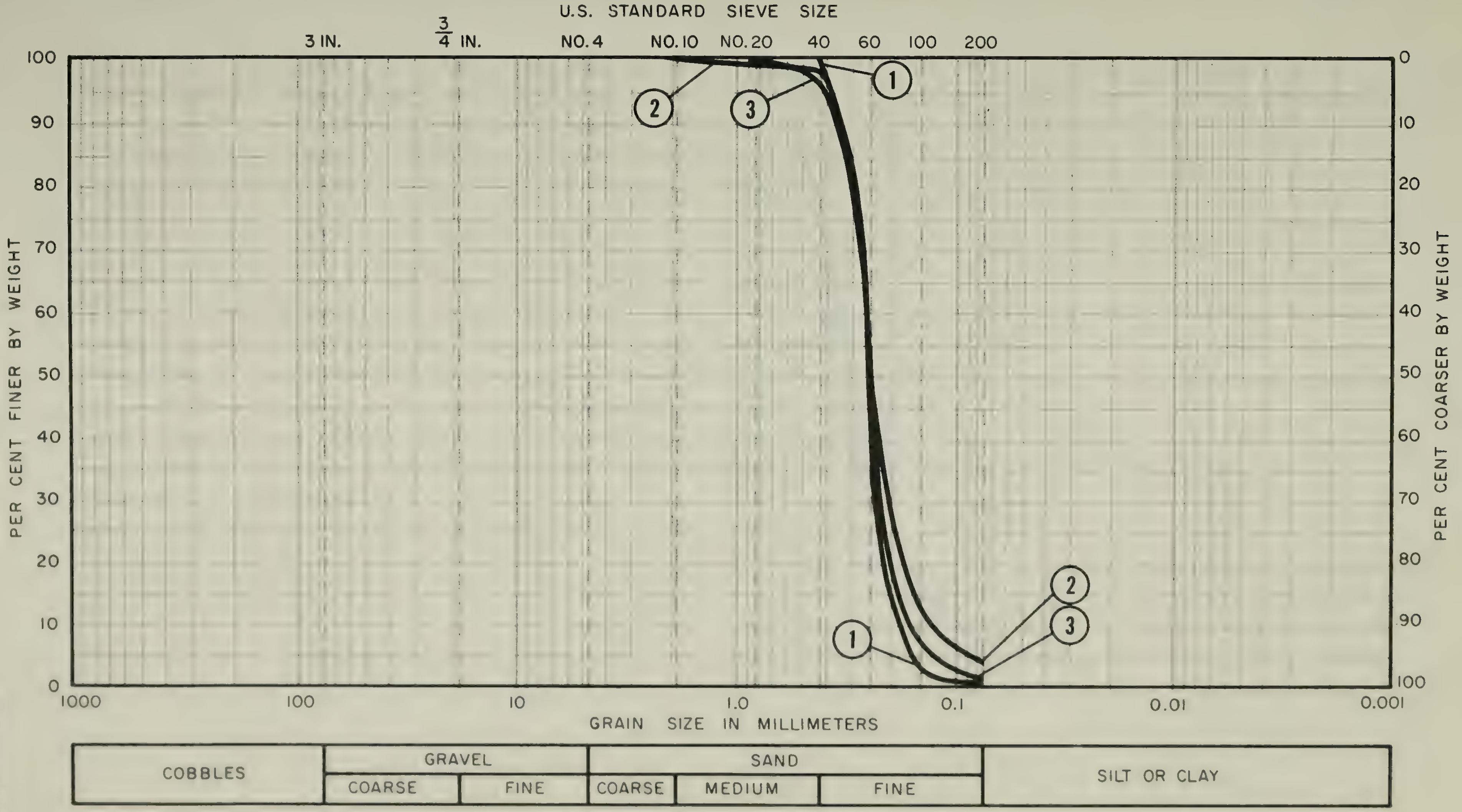
## GRAIN-SIZE DISTRIBUTION
## (unified soil classification system)

| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 22 | 70.9 | +204.1 | 6 | COLMA |  | SM/SP | BROWN SILTY FINE SAND | ① |
| 22 | 94.0 | +181.0 | 8 | COLMA |  | SP/SM | LT. BROWN SLIGHTLY SILTY FINE SA. | ② |
| 22 | 105.5 | +169.5 | 9 | COLMA |  | SP | LIGHT BROWN FINE SAND | ③ |
| 22 | 125.5 | +149.5 | 10 | COLMA |  | SM | DARK BROWN SILTY FINE SAND | ④ |



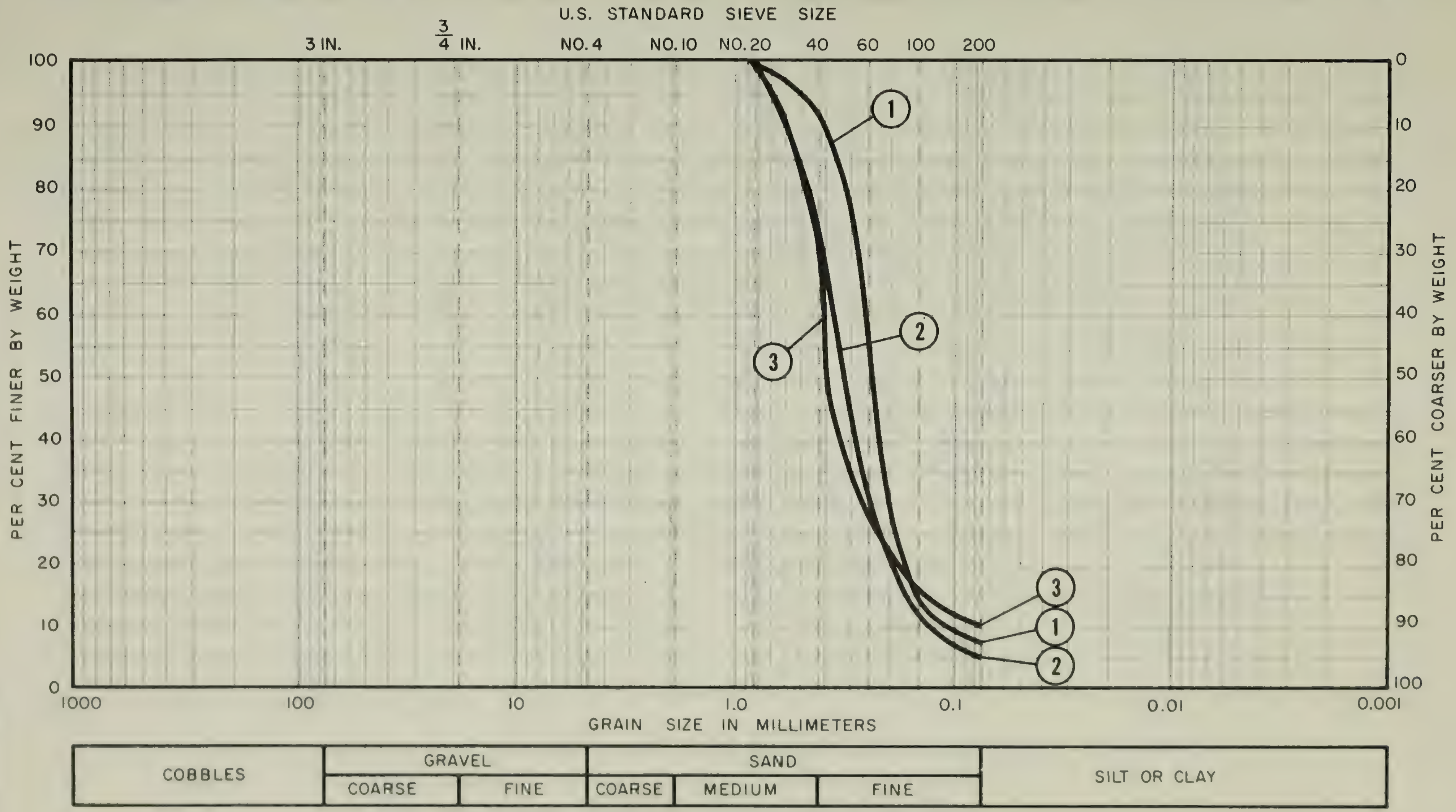
# GRAIN-SIZE DISTRIBUTION
(unified soil classification system)

| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 24 | 24.7 | +60.3 | 7 | DUNE | | SP | LIGHT BROWN FINE SAND | ① |
| 24 | 39.3 | +45.7 | 11 | DUNE | | SP | DARK BROWN FINE SAND | ② |
| 24 | 54.8 | +30.2 | 16 | DUNE | $2 \times 10^{-3}$ | SP | LIGHT BROWN FINE SAND | ③ |
| | | | | | | | | |



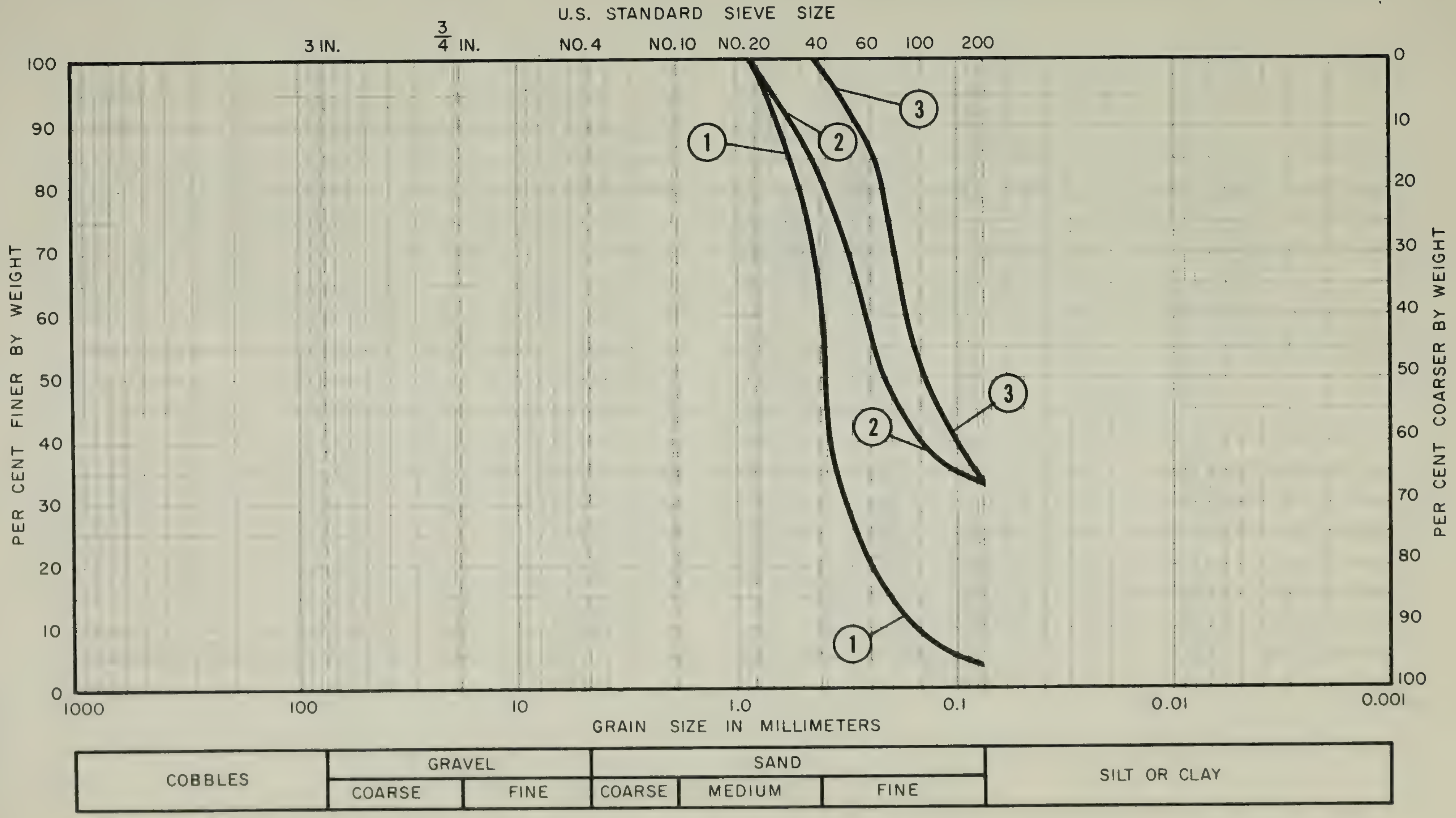
## GRAIN-SIZE DISTRIBUTION
(unified soil classification system)

| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 24 | 64.5 | +20.5 | 19 | DUNE | $1\text{x}10^{-5}$ | SP | GRAY BROWN FINE SAND | ① |
| 24 | 69.6 | +15.4 | 20 | COLMA |  | SP | LIGHT BROWN FINE SAND | ② |
| 24 | 74.5 | +10.5 | 22 | COLMA |  | SP/SM | RED-BROWN SLIGHTLY SILTY FINE SA. | ③ |
|  |  |  |  |  |  |  |  |  |



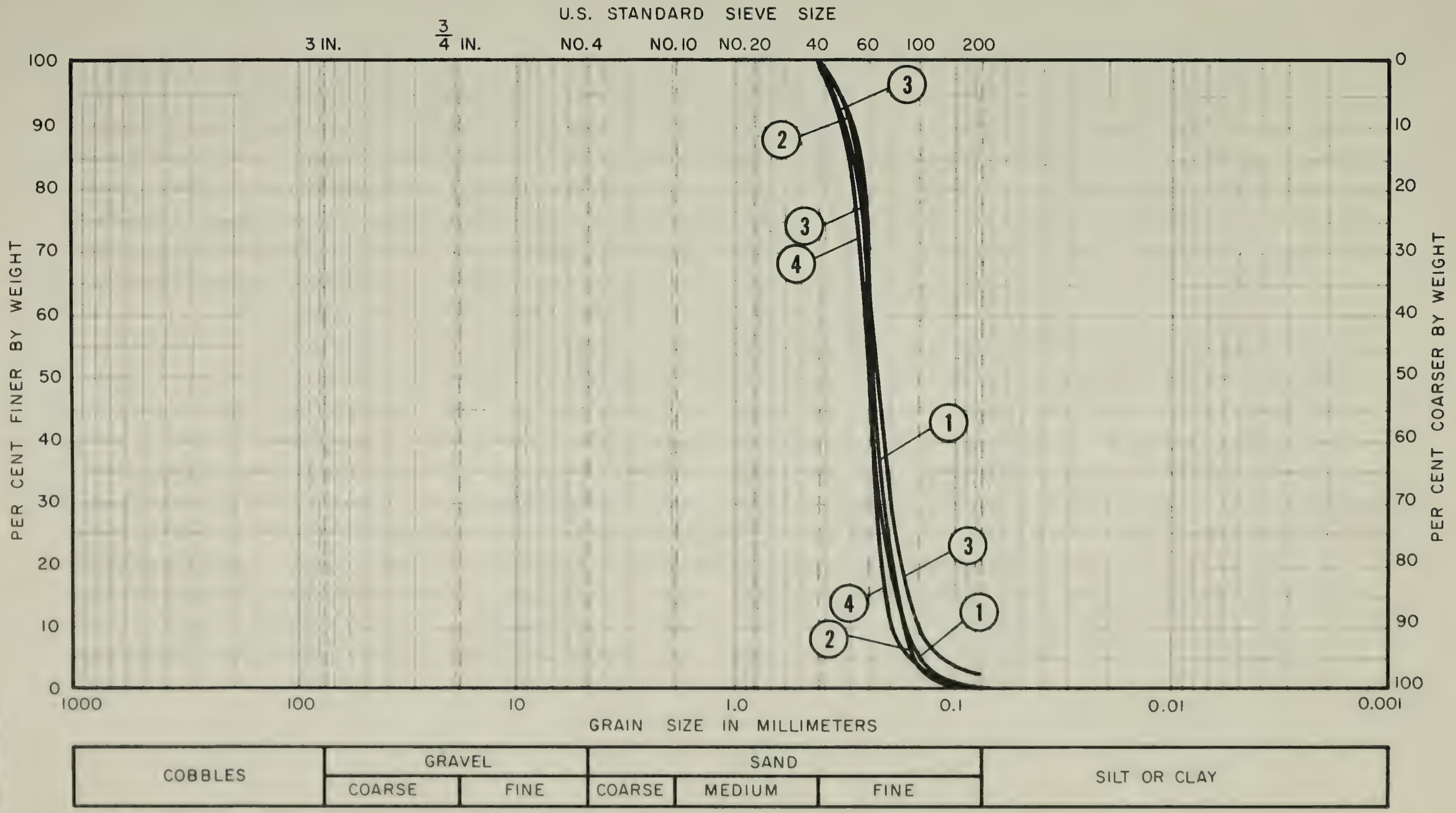
## GRAIN-SIZE DISTRIBUTION
## (unified soil classification system)

| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 24 | 76.1 | +8.9 | 23 | COLMA | | SP | GREENISH BROWN MED-FINE SAND | ① |
| 24 | 79.5 | +5.5 | 24A | COLMA | $2x10^{-8}$ | SM | LIGHT BROWN SILTY FINE SAND | ② |
| 24 | 80.0 | +5.0 | 24B | COLMA | | SM | BROWN SILTY FINE SAND | ③ |
| | | | | | | | | |



# GRAIN-SIZE DISTRIBUTION
(unified soil classification system)

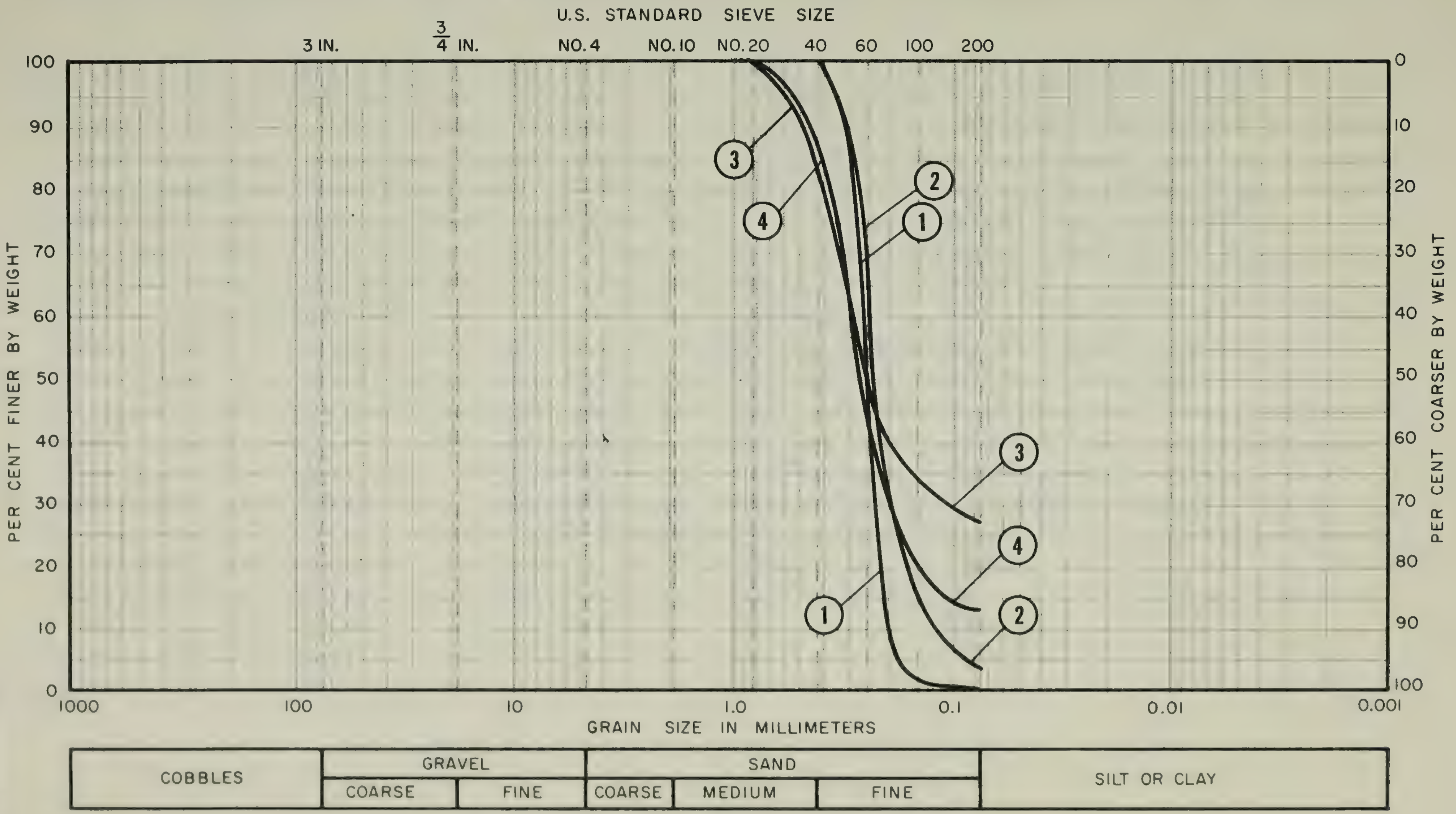
| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 25 | 35.8 | +63 | 8 | DUNE |  | SP | DARK BROWN FINE SAND | ① |
| 25 | 46.0 | +53 | 11 | DUNE | $7\times10^{-4}$ | SP | DARK GRAY BROWN FINE SAND | ② |
| 25 | 50.7 | +48 | 12 | DUNE |  | SP | DARK BROWN FINE SAND | ③ |
| 25 | 55.7 | +43 | 13 | DUNE |  | SP | DARK BROWN FINE SAND | ④ |



# GRAIN-SIZE DISTRIBUTION
## (unified soil classification system)

**DAMES & MOORE**

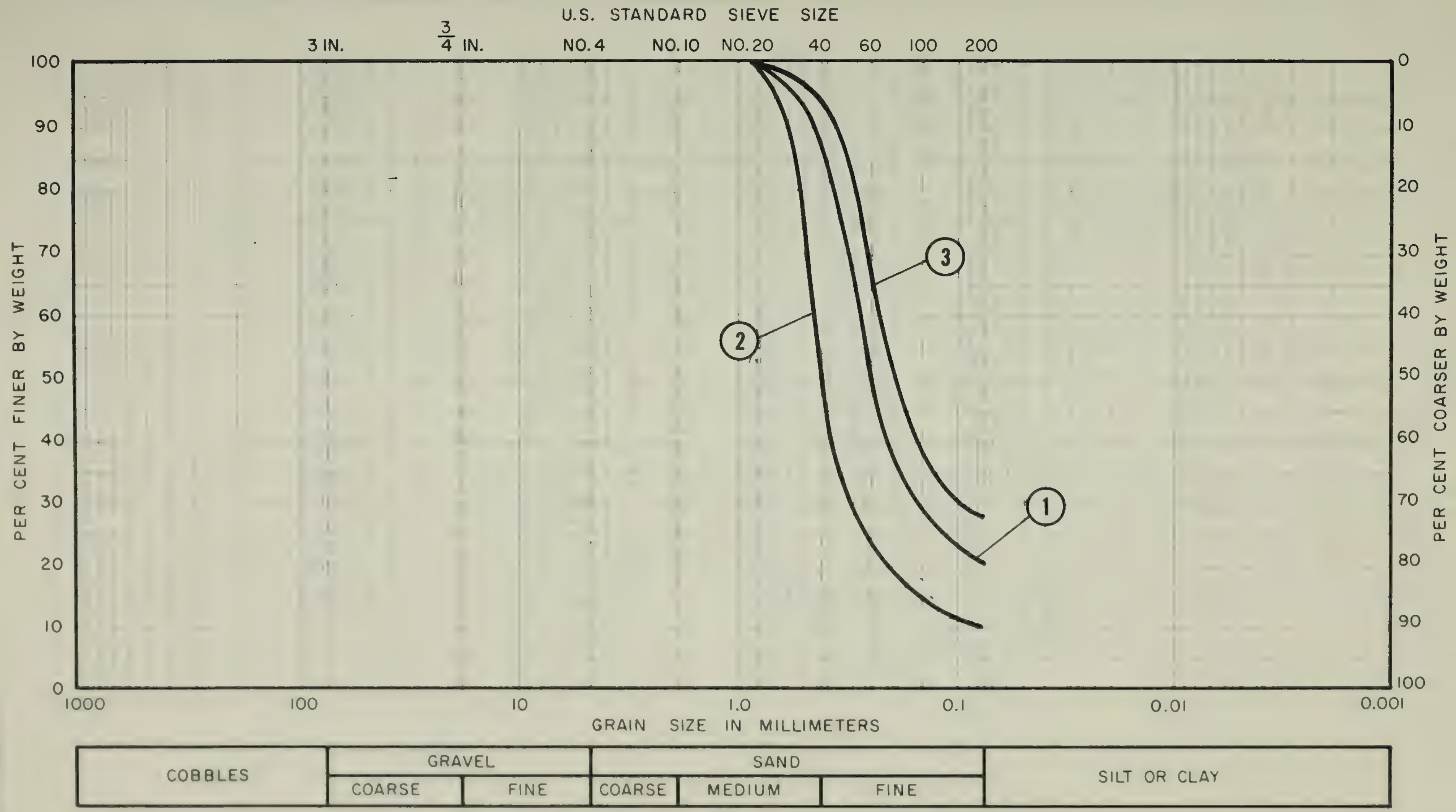
| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 25 | 60.3 | +39 | 15 | DUNE |  | SP | BROWN FINE SAND | ① |
| 25 | 65.5 | +34 | 16 | DUNE |  | SP | BROWN FINE SAND | ② |
| 25 | 70.5 | +29 | 18 | COLMA |  | SM | RED-BROWN SILTY FINE SAND | ③ |
| 25 | 75.6 | +23 | 19 | COLMA | $2 \times 10^{-7}$ | SM | RED-BROWN SILTY FINE SAND | ④ |



# GRAIN-SIZE DISTRIBUTION
## (unified soil classification system)

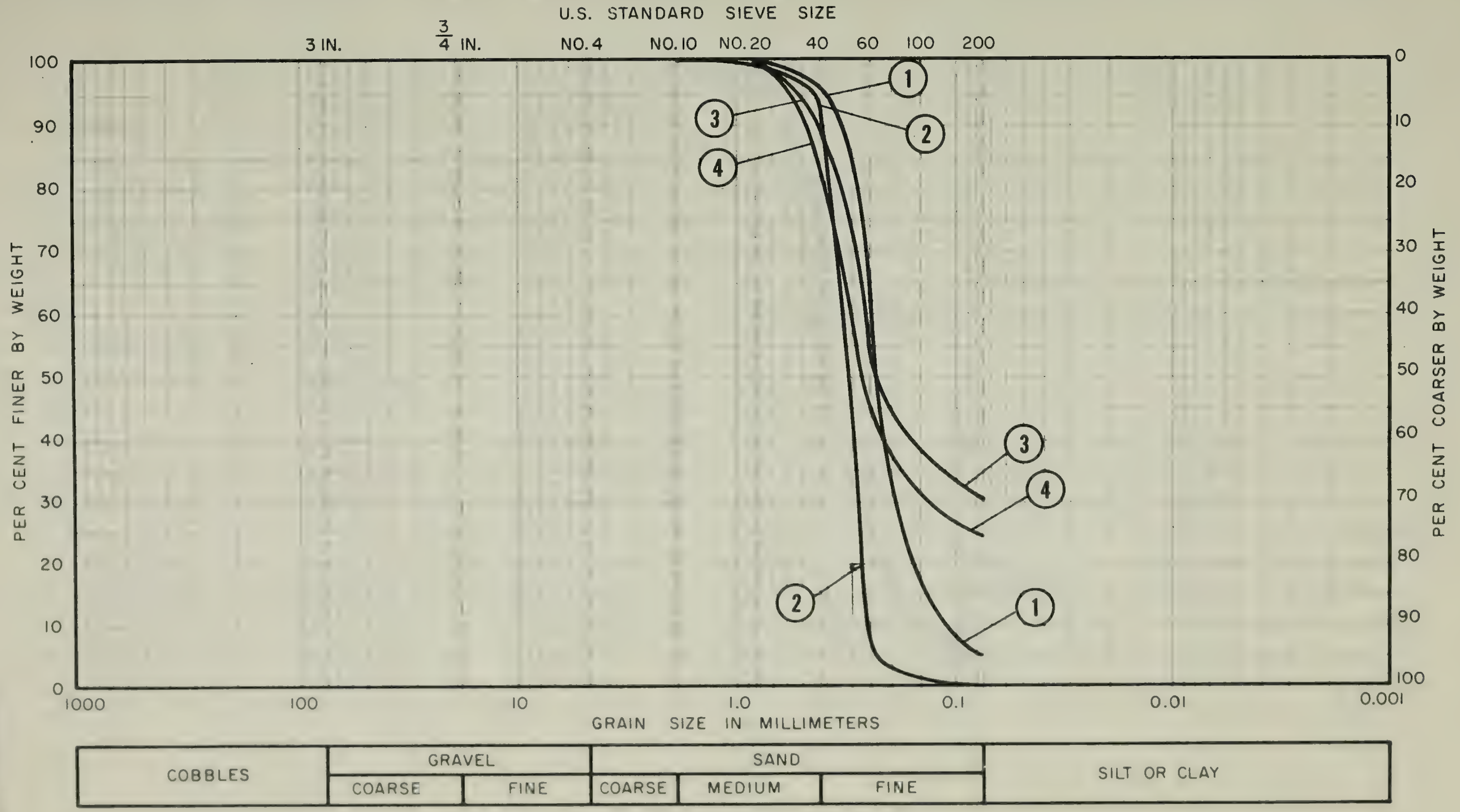
DAMES & MOORE

| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 25 | 80.7 | +18 | 21 | COLMA |  | SM | DARK BROWN SILTY FINE SAND | ① |
| 25 | 85.3 | +14 | 22 | COLMA |  | SP/SM | RED-BRN SILTY FINE SAND(CEMENTED) | ② |
| 25 | 90.6 | +8 | 23 | COLMA | $8 \times 10^{-7}$ | SM | RED-BRN SILTY FINE SAND(CEMENTED) | ③ |
|  |  |  |  |  |  |  |  |  |



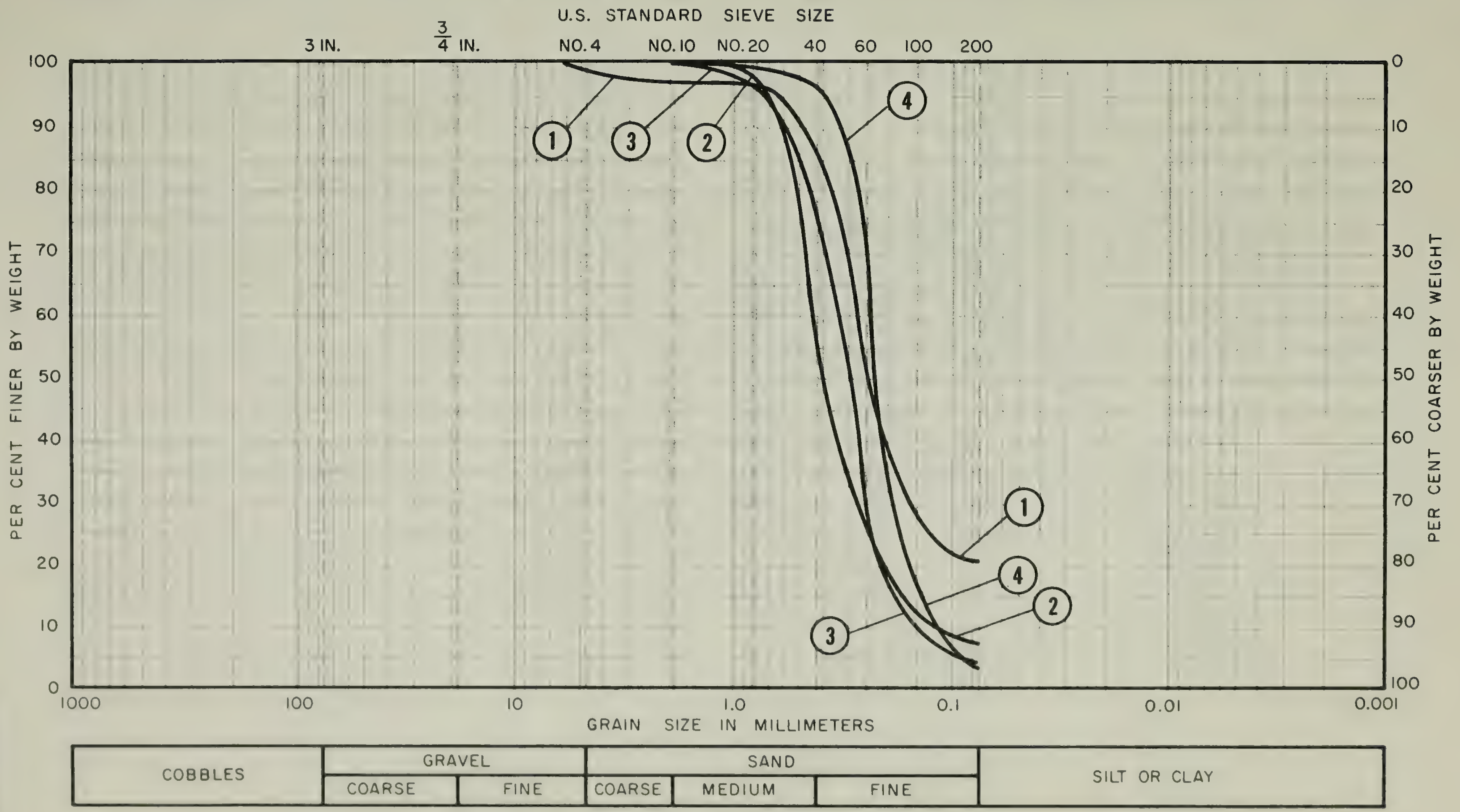
# GRAIN-SIZE DISTRIBUTION
## (unified soil classification system)

| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 26 | 40.6 | +67 | 7 | DUNE | $5\times10^{-4}$ | SP | DARK GRAY-BROWN FINE SAND | ① |
| 26 | 45.5 | +63 | 8 | DUNE |  | SP | DARK BROWN FINE SAND | ② |
| 26 | 52.0 | +56 | 10 | COLMA |  | SM | BROWN SILTY FINE SAND | ③ |
| 26 | 55.5 | +53 | 11 | COLMA | $2\times10^{-6}$ | SM | RED-BROWN SILTY FINE SAND | ④ |



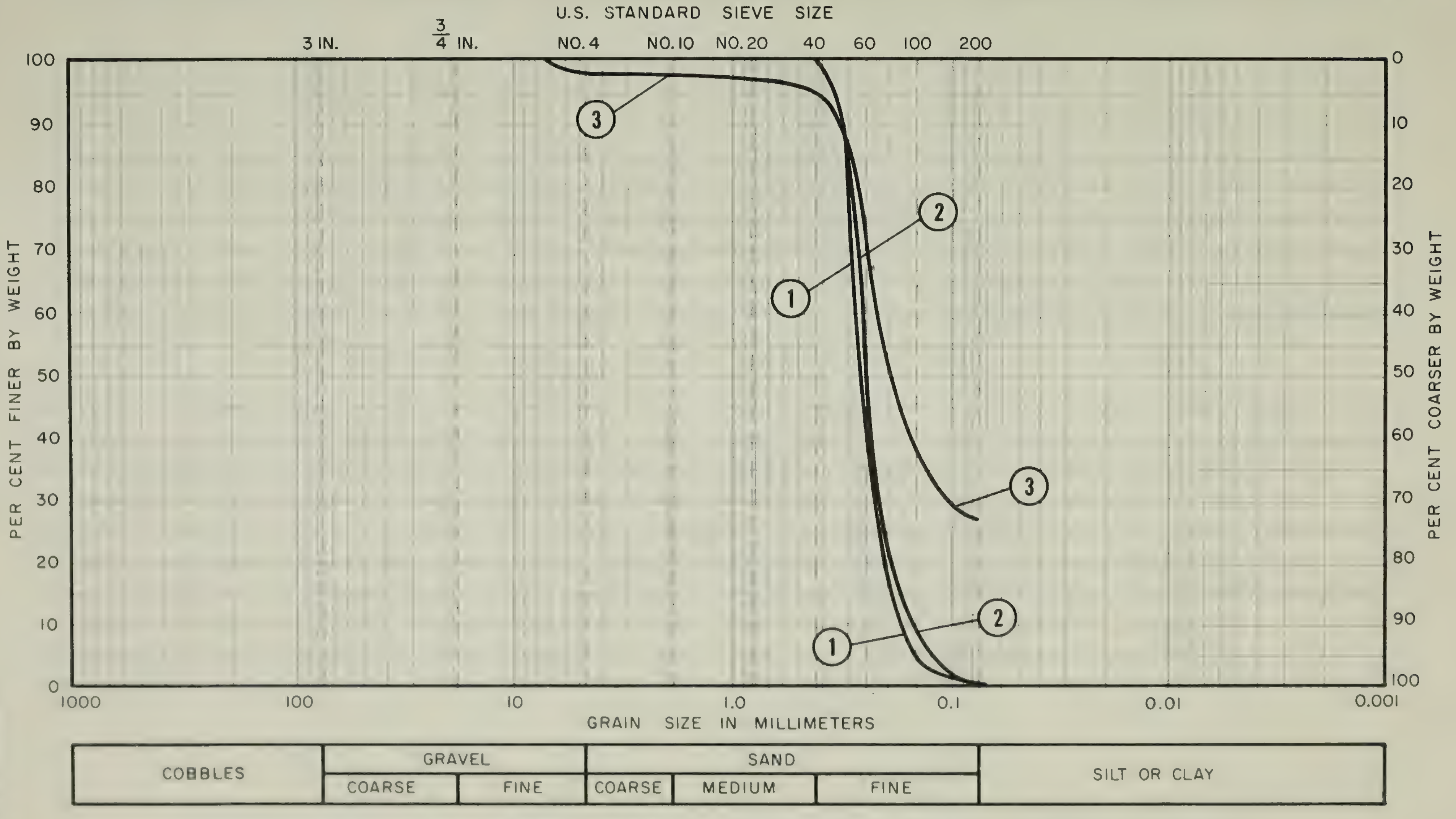
# GRAIN-SIZE DISTRIBUTION
(unified soil classification system)

| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 26 | 60.5 | +48 | 12 | COLMA | | SM | RED-BRN SILTY FINE SAND(CEMENTED) | ① |
| 26 | 65.2 | +43 | 13 | COLMA | | SP/SM | RED-BROWN FINE SAND (CEMENTED) | ② |
| 26 | 70.2 | +38 | 14 | COLMA | | SP/SM | RED-BROWN FINE SAND (CEMENTED) | ③ |
| 26 | 85.2 | +23 | 16 | COLMA | | SP/SM | RED-BROWN FINE SAND (CEMENTED) | ④ |



# GRAIN-SIZE DISTRIBUTION
(unified soil classification system)

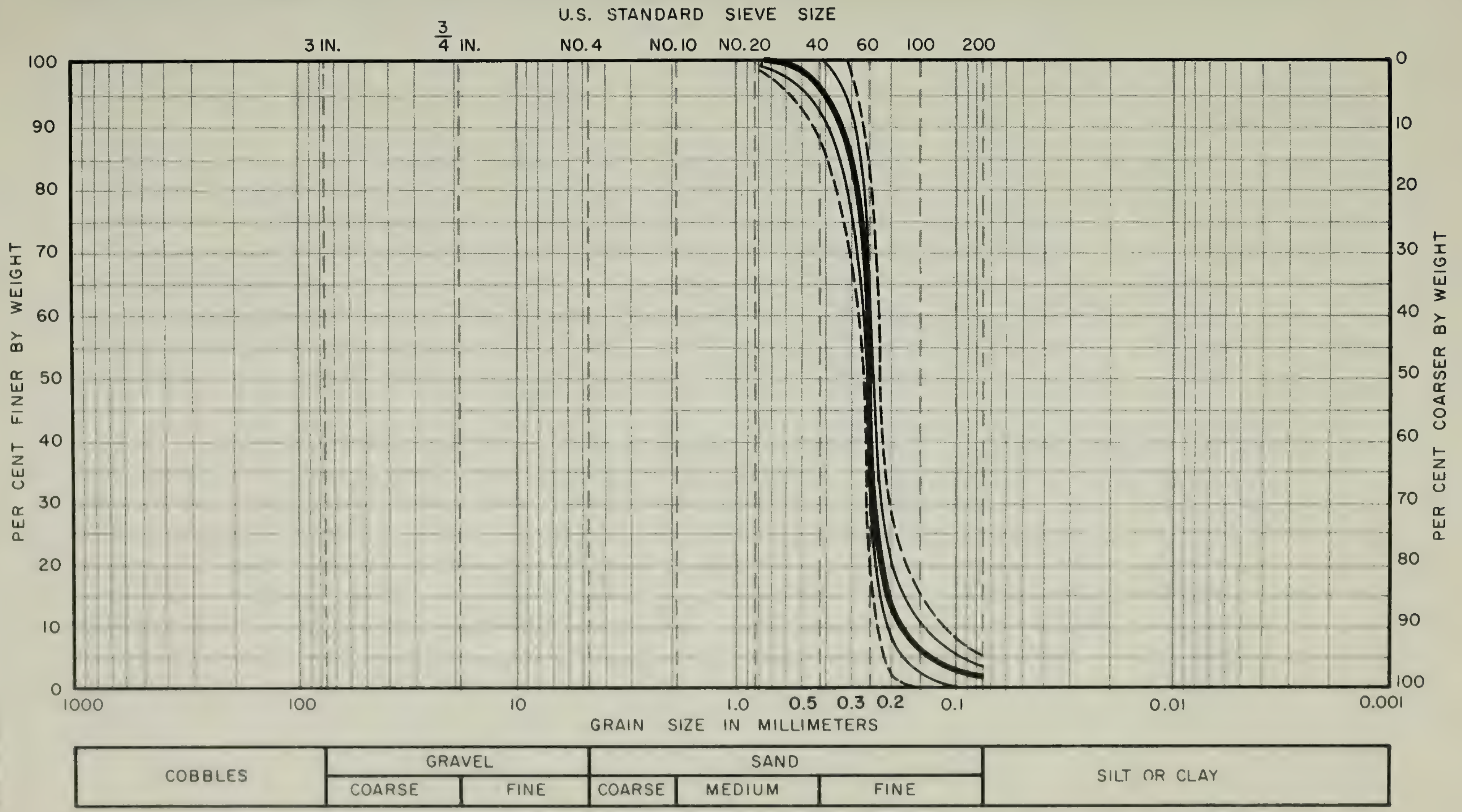
| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 31 | 25.5 | +99 | 6 | DUNE |  | SP | GRAY FINE SAND | ① |
| 31 | 30.3 | +94 | 7 | DUNE |  | SP | DARK GRAY-BROWN FINE SAND | ② |
| 31 | 40.5 | +84 | 9 | COLMA |  | SC | RED-BROWN SILTY CLAYEY FINE SAND | ③ |
|  |  |  |  |  |  |  |  |  |



## GRAIN-SIZE DISTRIBUTION
(unified soil classification system)

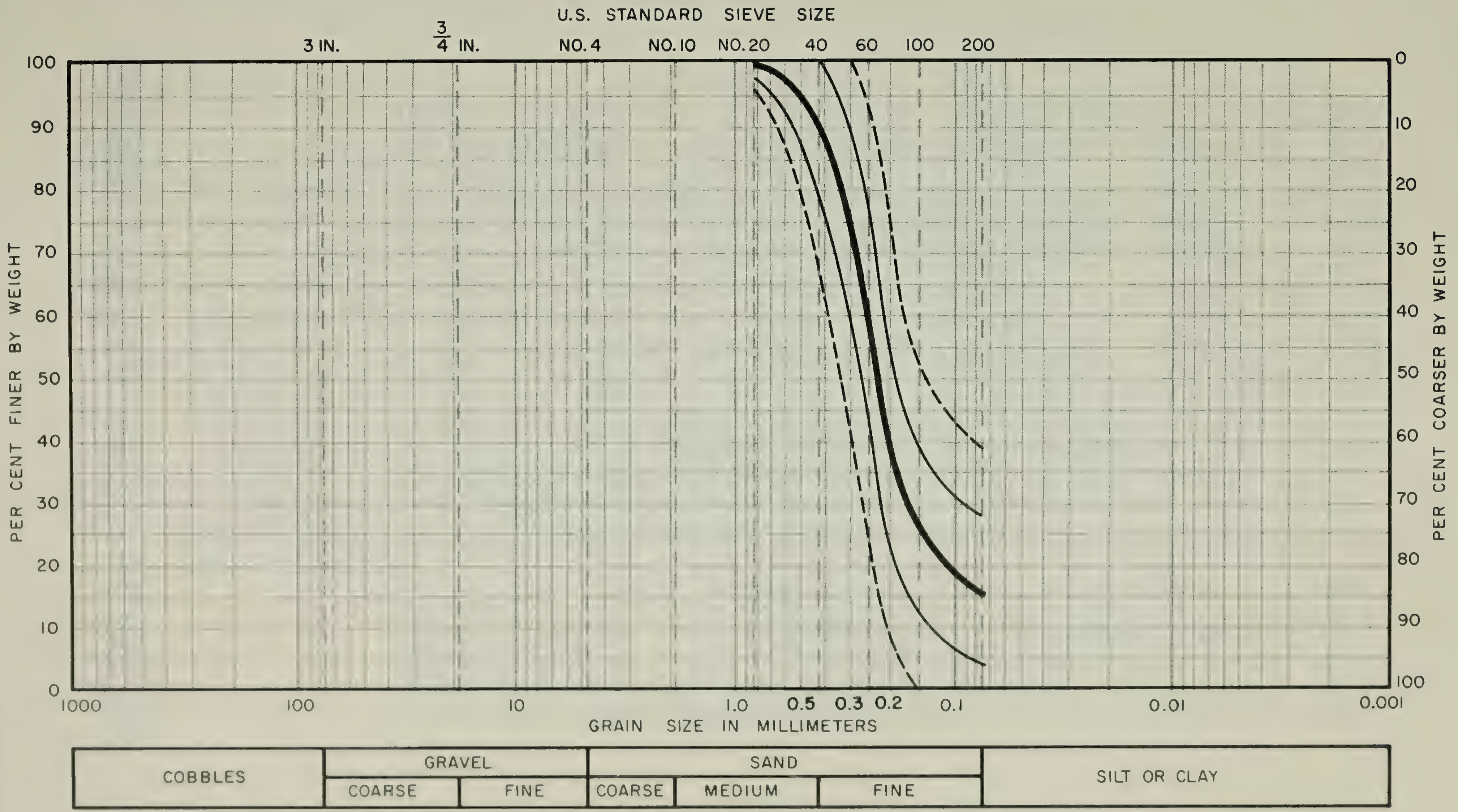
**DAMES & MOORE**

| SUMMARY OF ALL DUNE SAND SAMPLES (26 SAMPLES) | LEGEND | KEY |
|---|---|---|
| | MEDIAN GRAIN-SIZE CURVE | ━━ |
| | STANDARD DEVIATION | ── |
| | 2x STANDARD DEVIATION | ---- |
| REVISED 11/30/78, MWS | | |



## SUMMARY OF GRAIN-SIZE DISTRIBUTION, DUNE SAND
(unified soil classification system)

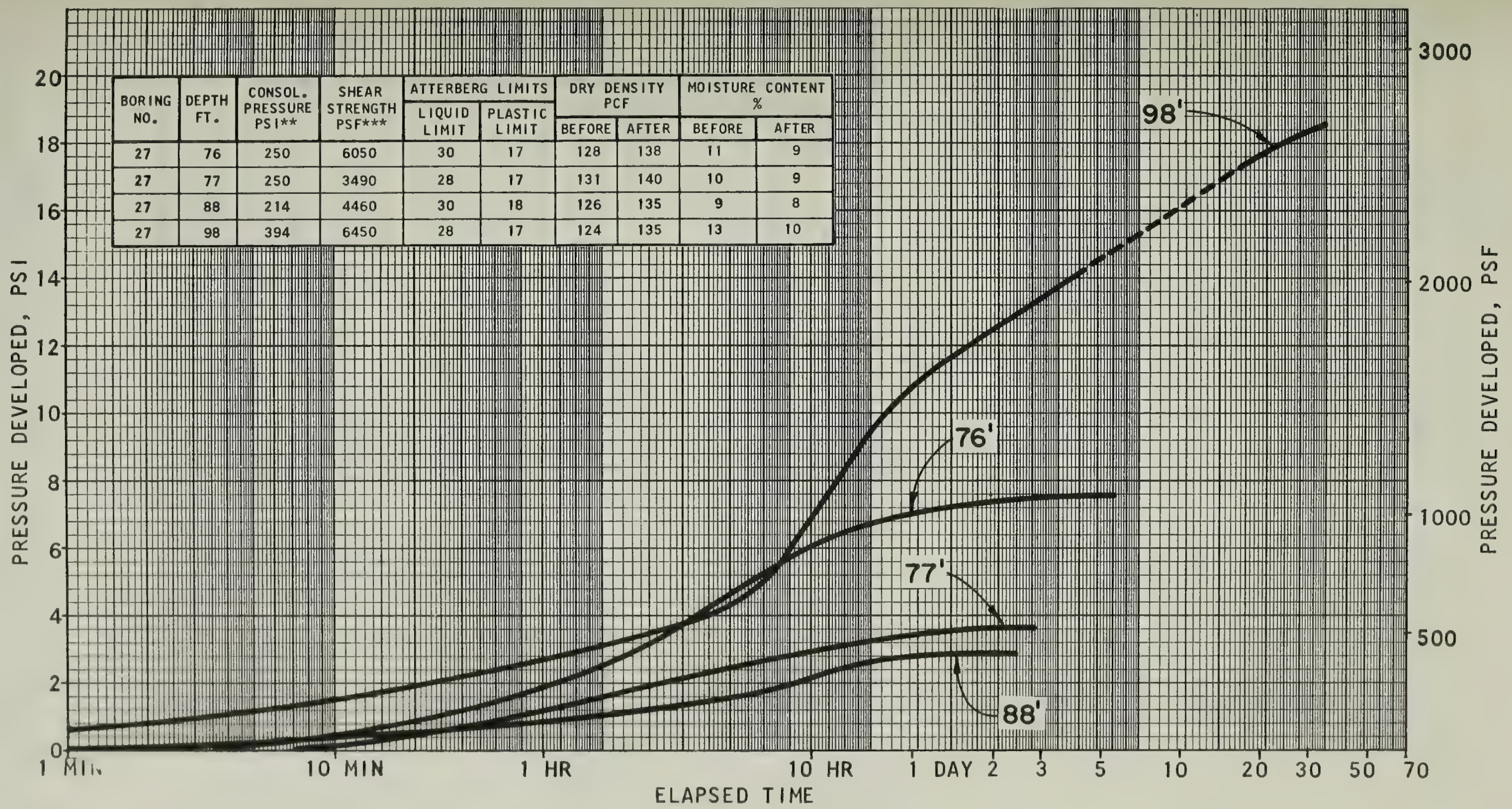
| SUMMARY OF ALL COLMA SAND SAMPLES (64 SAMPLES) | LEGEND | KEY |
|---|---|---|
|  | MEDIAN GRAIN-SIZE CURVE | ━━ |
|  | STANDARD DEVIATION | ── |
|  | 2x STANDARD DEVIATION | - - - |
| REVISED 11/30/78, MWS |  |  |



# SUMMARY OF GRAIN-SIZE DISTRIBUTION, COLMA SAND
(unified soil classification system)

| BORING | DEPTH | SOIL TYPE | % FINES | PERMEABILITY k cm/sec |
|---|---|---|---|---|
| 3 | 120 | COLMA | 17.2 | $2x10^{-7}$ |
| 7 | 85' | " | 12.4 | $2x10^{-6}$ |
| 9 | 146' | " | 6.2 | $2x10^{-5}$ |
| 12 | 121' | " | 1.3 | $7x10^{-4}$ |
| 14 | 96' | " | 10.3 | $1x10^{-6}$ |
| 16 | 176' | " | 2.8 | $2x10^{-3}$ |
| 20 | 27' | " | 34.9 | $1x10^{-6}$ |
| 20 | 41' | " | 21.8 | $1x10^{-7}$ |
| 21 | 125' | " | 5.3 | $2x10^{-4}$ |
| 21 | 140' | " | 5.4 | $2x10^{-4}$ |
| 22 | 83' | " | 21.1 | $2x10^{-4}$ |
| 24 | 80' | " | 34.0 | $2x10^{-8}$ |
| 25 | 76' | " | 14.4 | $2x10^{-7}$ |
| 25 | 91' | " | 27.1 | $8x10^{-7}$ |
| 26 | 56' | " | 25.7 | $2x10^{-6}$ |
| | | | | |
| | | | | |
| 5 | 39' | DUNE | 3.1 | $2x10^{-3}$ |
| 10 | 35' | " | 1.4 | $4x10^{-3}$ |
| 24 | 55' | " | 2.4 | $2x10^{-3}$ |
| 24 | 65' | " | 7.3 | $1x10^{-5}$ |
| 25 | 46' | " | <1 | $7x10^{-4}$ |
| 26 | 41' | " | 5.1 | $5x10^{-4}$ |

# PERMEABILITY TEST RESULTS



| BORING NO. | DEPTH FT. | CONSOL. PRESSURE PSI** | SHEAR STRENGTH PSF*** | ATTERBERG LIMITS |  | DRY DENSITY PCF |  | MOISTURE CONTENT % |  |
|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  | LIQUID LIMIT | PLASTIC LIMIT | BEFORE | AFTER | BEFORE | AFTER |
| 27 | 76 | 250 | 6050 | 30 | 17 | 128 | 138 | 11 | 9 |
| 27 | 77 | 250 | 3490 | 28 | 17 | 131 | 140 | 10 | 9 |
| 27 | 88 | 214 | 4460 | 30 | 18 | 126 | 135 | 9 | 8 |
| 27 | 98 | 394 | 6450 | 28 | 17 | 124 | 135 | 13 | 10 |

NOTES:

* SEE TEXT OF APPENDIX A FOR A DESCRIPTION OF MELANGE AND OF THE METHOD USED TO PERFORM THESE TESTS.

** PRESSURE UNDER WHICH THE SAMPLE WAS CONSOLIDATED BEFORE START OF SWELL PRESSURE TEST.

*** FOLLOWING THE SWELL PRESSURE TEST.

# RESULTS OF SWELL PRESSURE TESTS ON SHEARED SHALE SAMPLES (MELANGE)*

| SAMPLE BORING/DEPTH(Ft.) | "OILY" SUBSTANCE 13/300± | FRANCISCAN SHALE 27/88 | FRANCISCAN SHALE 28/300 | FRANCISCAN SHALE 28/227 | GT. VALLEY SHALE 15/135 |
|---|---|---|---|---|---|
| Detectable Odor | No | No | No | No | No |
| Evidence of Crystalline(1) Structure (X-Ray Diffract) | No | Yes | Yes | Yes | Yes |
| Volatile Fraction @ 500°c(2) (after drying) | 94.0 | NM | NM | NM | NM |
| Carbon(3) | 51.88 | 0.61 | 0.69 | 0.72 | 1.74 |
| Hydrogen (after drying)(3) | 6.01 | 1.01 | 1.06 | 0.98 | 0.58 |
| Carbon After HCL | 46.77 | 0.47 | 0.54 | 0.55 | 0.68 |
| Hydrogen treatment**(3) | 5.58 | 2.44 | 2.24 | 1.87 | 1.31 |
| Sulfate($SO_4$)(2) | <0.0050 | NM | NM | NM | NM |
| Other Elements(3),(4) | | | | | |
| Silicon | 0.0998 | 25. | 24. | 24. | 24. |
| Iron | 0.0998 | 3.5 | 5.2 | 4.3 | 6.5 |
| Aluminum | 0.0396 | 11. | 8.2 | 11. | 10. |
| Magnesium* | 0.0690 | 8.3 | 12. | 7.2 | 3.5 |
| Calcium* | 0.0590 | 1.2 | 1.6 | 1.6 | 0.85 |
| Chromium | 0.0012 | 0.12 | 0.15 | 0.067 | 0.014 |
| Nickel | 0.0050 | 0.12 | 0.11 | 0.067 | 0.0081 |
| Titanium | 0.0036 | 0.18 | 0.33 | 0.39 | 0.42 |
| Barium | 0.0010 | TR<0.10 | ND<0.10 | TR<0.10 | TR<0.10 |
| Boron | 0.0009 | 0.0029 | 0.0019 | 0.0025 | 0.0075 |
| Lead | 0.0144 | TR<0.01 | ND<0.01 | TR<0.01 | TR<0.01 |
| Gallium | NM | ND<0.003 | TR<0.003 | 0.011 | 0.012 |
| Manganese | NM | 0.065 | 0.049 | 0.062 | 0.046 |
| Vanadium | NM | 0.0071 | 0.0099 | 0.0097 | 0.013 |
| Copper | 0.0155 | 0.0054 | 0.011 | 0.0075 | 0.0073 |
| Sodium | 0.0245 | 0.62 | 1.4 | 2.9 | 4.4 |
| Zirconium | NM | 0.0081 | 0.011 | 0.014 | 0.016 |
| Cobalt | NM | 0.015 | 0.021 | 0.012 | 0.0056 |
| Potassium | NM | TR<0.10 | TR<0.10 | 0.97 | 4.6 |
| Strontium | NM | 0.029 | 0.047 | 0.044 | 0.064 |
| Silver | TR<0.0001 | nil | nil | nil | nil |
| Tin | 0.0016 | nil | nil | nil | nil |
| Phosphorous* | 0.0220 | nil | nil | nil | nil |
| Zinc* | 0.0770 | nil | nil | nil | nil |
| Other Elements | NM | nil | nil | nil | nil |

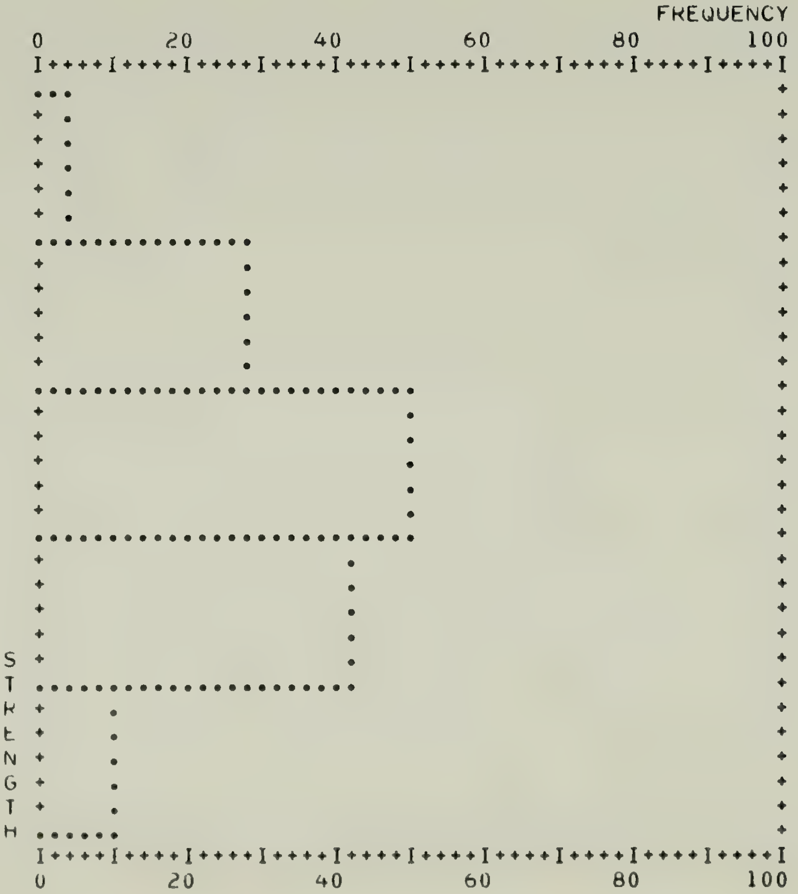
All measurements in % weight
* Elements normally found in refined oil additives
** To remove carbonate minerals if present
NM= Not measured; TR=Trace; ND=None detected
(1) University of California, Berkeley
(2) Pacific Environmental Laboratory, San Francisco
(3) Analysts, Inc., Oakland
(4) Elek Microanalytical Laboratories, Torrance

# ANALYSIS OF BLACK "OILY" APPEARING SUBSTANCE SKIMMED FROM WASH WATER WHILE CORING FRANCISCAN SHALE AND COMPARISON WITH SHALE SAMPLES

DAMES & MOORE

| ROCK TYPE | MEDIAN (PSI) | MEAN (PSI) | STD. DVN. (PSI) | CO. OF VARN. | NO. OF SAMPLES |
|---|---|---|---|---|---|
| GRAYWACKE | 7461. | 10258. | 8886. | .866 | 139 |

HISTOGRAM OF STRENGTH



| STRENGTH | RANGE PSI | FREQUENCY FOR EACH CLASS INTERVAL | RELATIVE FREQUENCY (PERCENT) |
|---|---|---|---|
| VERY LOW | 0 - 1000 | 5 | 3.60 |
| LOW | 1000 - 3000 | 29 | 20.86 |
| MEDIUM | 3000 - 10000 | 51 | 36.69 |
| HIGH | 10000 - 25000 | 43 | 30.94 |
| VERY HIGH | 25000 - OVER | 11 | 7.91 |
|  |  | TOTAL=139 |  |

# SUMMARY OF POINT LOAD DATA

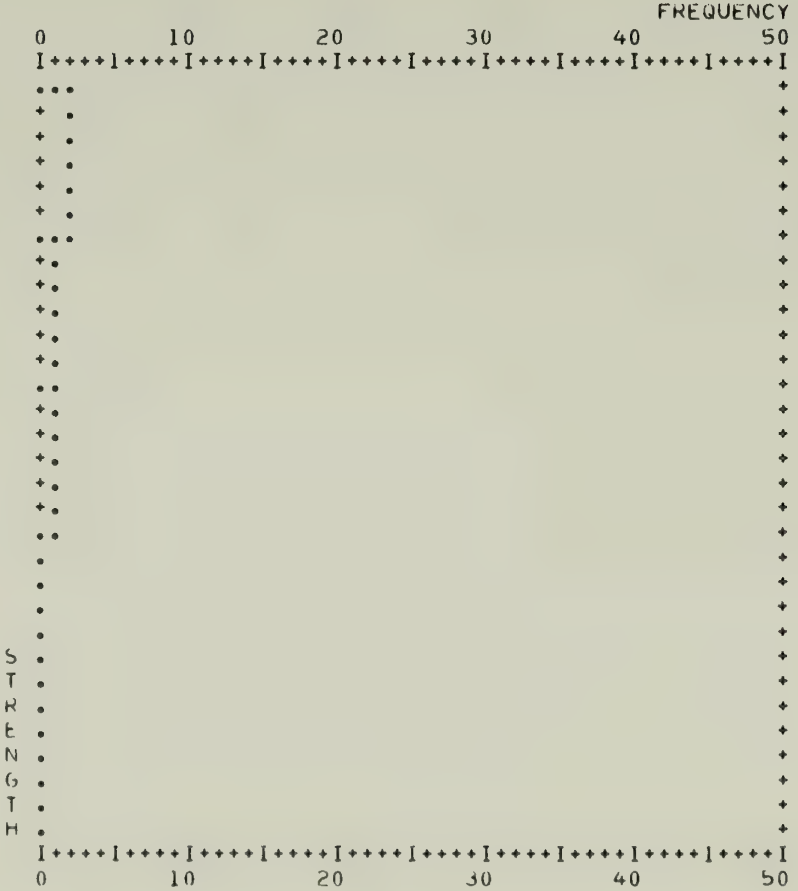
## GRAYWACKE

**DAMES & MOORE**

```
ROCK TYPE    MEDIAN (PSI)    MEAN (PSI)  STD. DVN. (PSI)  CO. OF VARN.  NO. OF SAMPLES

SILT-SH FR    983.            2871.         4168.           1.452              4
```

HISTOGRAM OF STRENGTH



```
STRENGTH       RANGE                  FREQUENCY          RELATIVE
                PSI                   FOR EACH           FREQUENCY
                                      CLASS INTERVAL     (PERCENT)

VERY LOW       0 -  1000                     2             50.00

     LOW    1000 -  3000                     1             25.00

  MEDIUM    3000 - 10000                     1             25.00

    HIGH   10000 - 25000                     0              0.00

VERY HIGH  25000 -  OVER                     0              0.00

                                      TOTAL= 4
```

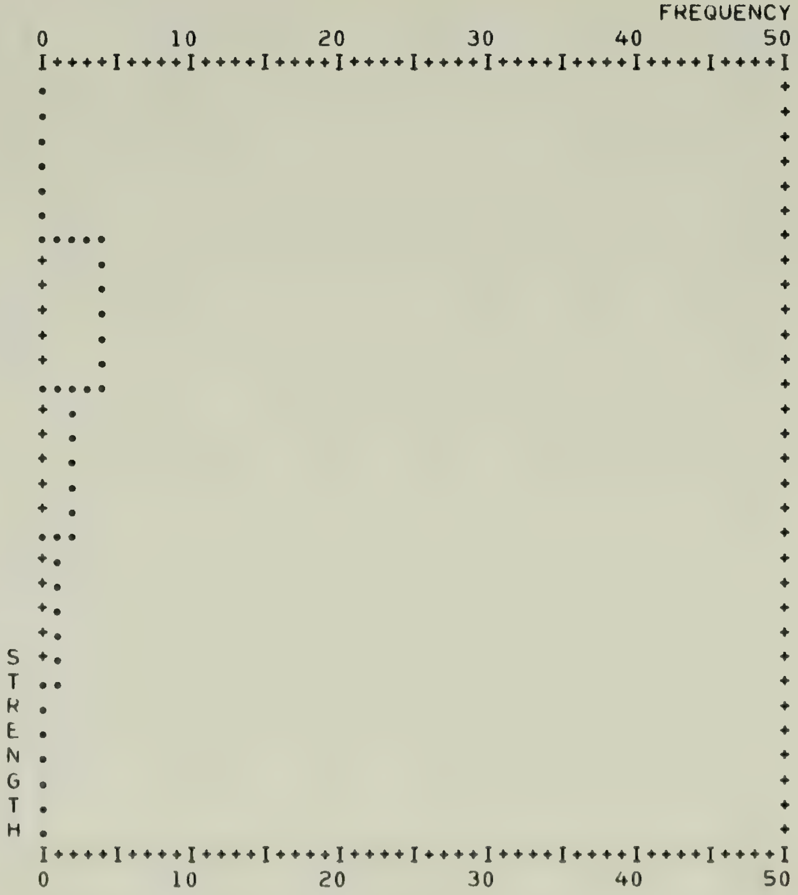
## SUMMARY OF POINT LOAD DATA

SILTSTONE AND SHALE (FRANCISCAN)

DAMES & MOORE

| ROCK TYPE | MEDIAN (PSI) | MEAN (PSI) | STD. DVN. (PSI) | CO. OF VARN. | NO. OF SAMPLES |
|---|---|---|---|---|---|
| GREENSTONE | 2978. | 5448. | 5681. | 1.043 | 7 |

HISTOGRAM OF STRENGTH



| STRENGTH | RANGE PSI | FREQUENCY FOR EACH CLASS INTERVAL | RELATIVE FREQUENCY (PERCENT) |
|---|---|---|---|
| VERY LOW | 0 - 1000 | 0 | 0.00 |
| LOW | 1000 - 3000 | 4 | 57.14 |
| MEDIUM | 3000 - 10000 | 2 | 28.57 |
| HIGH | 10000 - 25000 | 1 | 14.29 |
| VERY HIGH | 25000 - OVER | 0 | 0.00 |
|  |  | TOTAL= 7 |  |

# SUMMARY OF POINT LOAD DATA

## GREENSTONE

DAMES & MOORE

```
    ROCK TYPE    MEDIAN (PSI)    MEAN (PSI)  STD. DVN. (PSI)  CO. OF VARN.  NO. OF SAMPLES

    SERPENTINE    835.            4446.          6811.          1.532              7


                                                 HISTOGRAM OF STRENGTH


                                                                            FREQUENCY        FREQUENCY       RELATIVE
   STRENGTH      RANGE            0        10        20        30        40        50        FOR EACH         FREQUENCY
                  PSI             I++++I++++I++++I++++I++++I++++I++++I++++I++++I++++I        CLASS INTERVAL  (PERCENT)
                                  .....                                             +
                                  +   .                                             +
                                  +   .                                             +
   VERY LOW      0 -  1000        +   .                                             +                4         57.14
                                  +   .                                             +
                                  +   .                                             +
                                  .....                                             +
                                  +.                                                +
                                  +.                                                +
        LOW   1000 -  3000        +.                                                +                1         14.29
                                  +.                                                +
                                  +.                                                +
                                  ..                                                +
                                  .                                                 +
                                  .                                                 +
     MEDIUM   3000 - 10000        .                                                 +                0          0.00
                                  .                                                 +
                                  .                                                 +
                                  ...                                               +
                                  + .                                               +
                                  + .                                               +
       HIGH  10000 - 25000        + .                                               +                2         28.57
                                  + .                                               +
                                S + .                                               +
                                T ...                                               +
                                R .                                                 +
                                E .                                                 +
  VERY HIGH  25000 -  OVER      N .                                                 +                0          0.00
                                G .                                                 +
                                T .                                                 +
                                H .                                                 +
                                  I++++I++++I++++I++++I++++I++++I++++I++++I++++I++++I        TOTAL=  7
                                  0        10        20        30        40        50
```

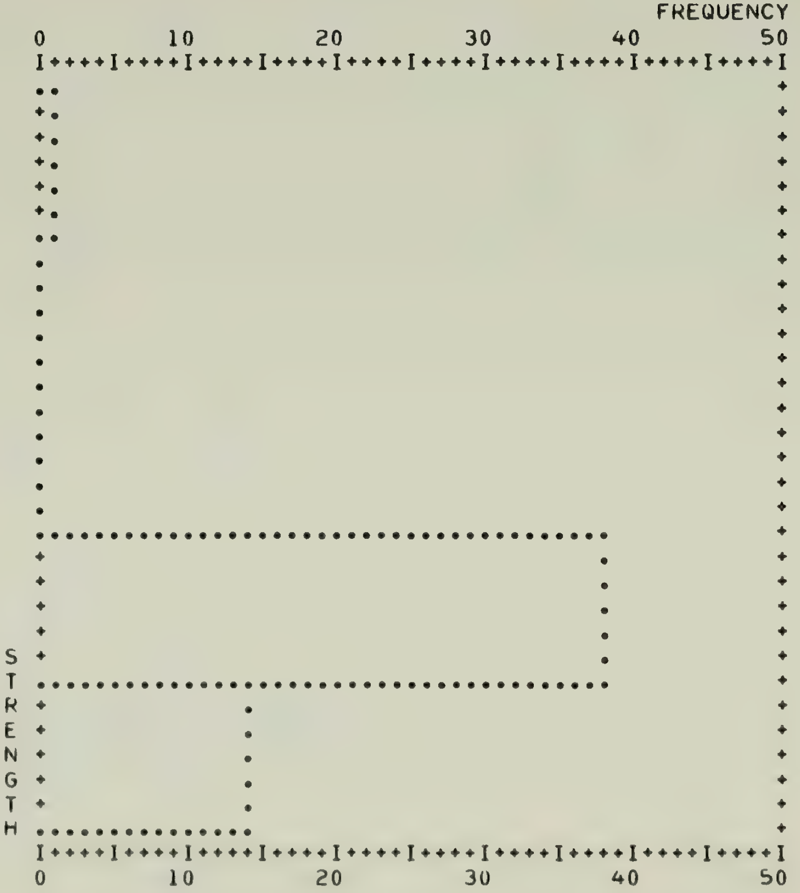
# SUMMARY OF POINT LOAD DATA

## SERPENTINE

```
ROCK TYPE    MEDIAN (PSI)    MEAN (PSI)  STD. DVN. (PSI)  CO. OF VARN.  NO. OF SAMPLES

SANDSTONE   19608.           20875.          7061.            .338             53
```

```
                                HISTOGRAM OF STRENGTH
```



```
STRENGTH        RANGE          FREQUENCY            RELATIVE
                 PSI           FOR EACH             FREQUENCY
                               CLASS INTERVAL       (PERCENT)

VERY LOW      0 -  1000              1                 1.89

     LOW   1000 -  3000              0                 0.00

  MEDIUM   3000 - 10000              0                 0.00

    HIGH  10000 - 25000             38                71.70

VERY HIGH 25000 -  OVER             14                26.42

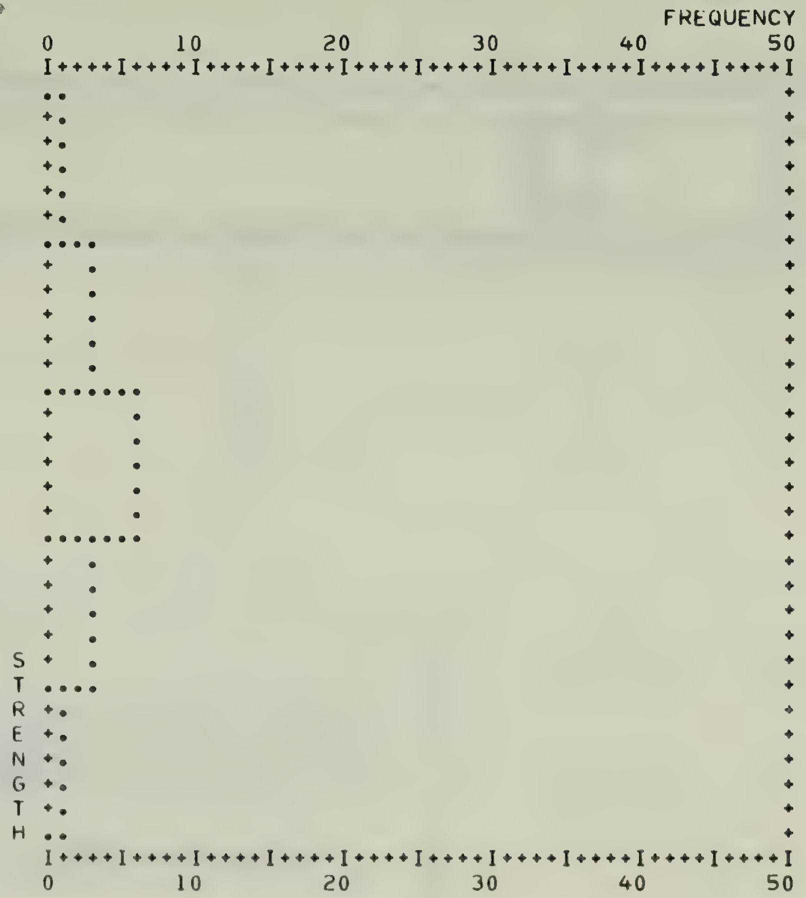
                               TOTAL= 53
```

## SUMMARY OF POINT LOAD DATA
### SANDSTONE ( GREAT VALLEY )

```
ROCK TYPE    MEDIAN (PSI)    MEAN (PSI)  STD. DVN. (PSI)  CO. OF VARN.  NO. OF SAMPLES

SILT-SH GV   4501.           11054.         21413.           1.937             14
```

HISTOGRAM OF STRENGTH



```
STRENGTH        RANGE                         FREQUENCY         RELATIVE
                 PSI                          FOR EACH          FREQUENCY
                                              CLASS INTERVAL    (PERCENT)

VERY LOW        0 -   1000                          1               7.14

     LOW     1000 -   3000                          3              21.43

  MEDIUM     3000 -  10000                          6              42.86

    HIGH    10000 -  25000                          3              21.43

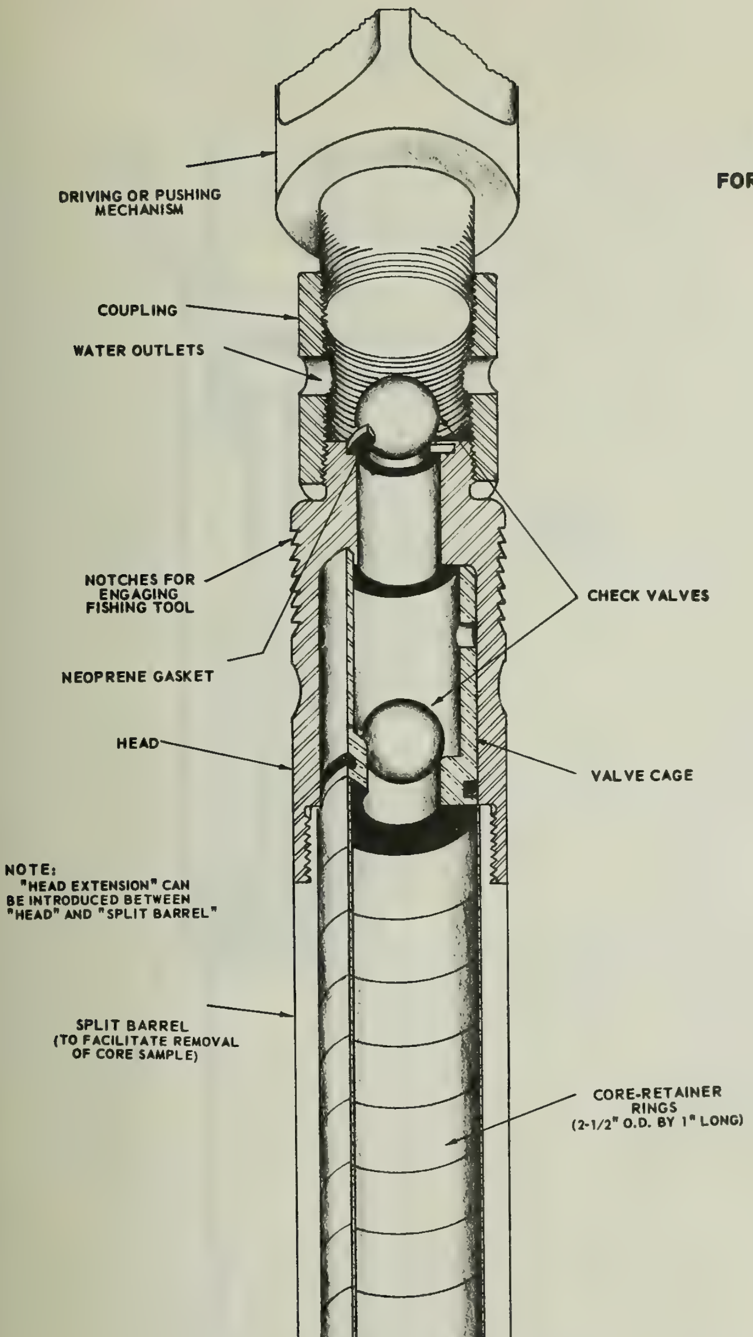
VERY HIGH   25000 -   OVER                          1               7.14

                                              TOTAL= 14
```

# SUMMARY OF POINT LOAD DATA
## SILTSTONE AND SHALE (GREAT VALLEY)

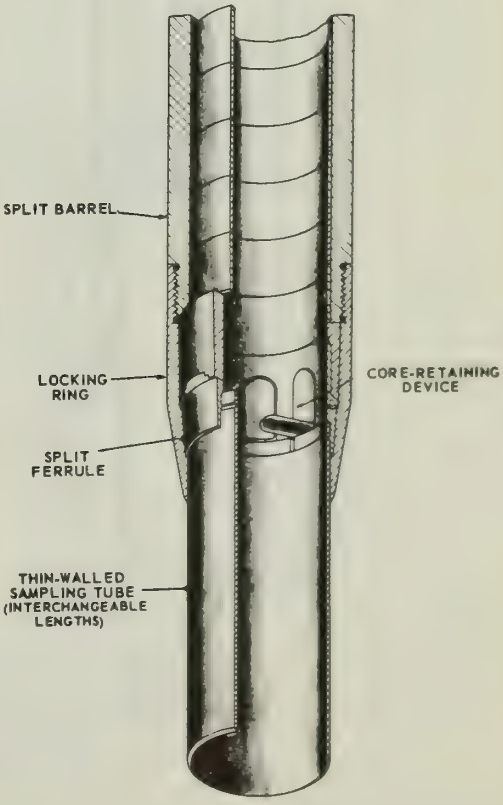
# SOIL SAMPLER TYPE U

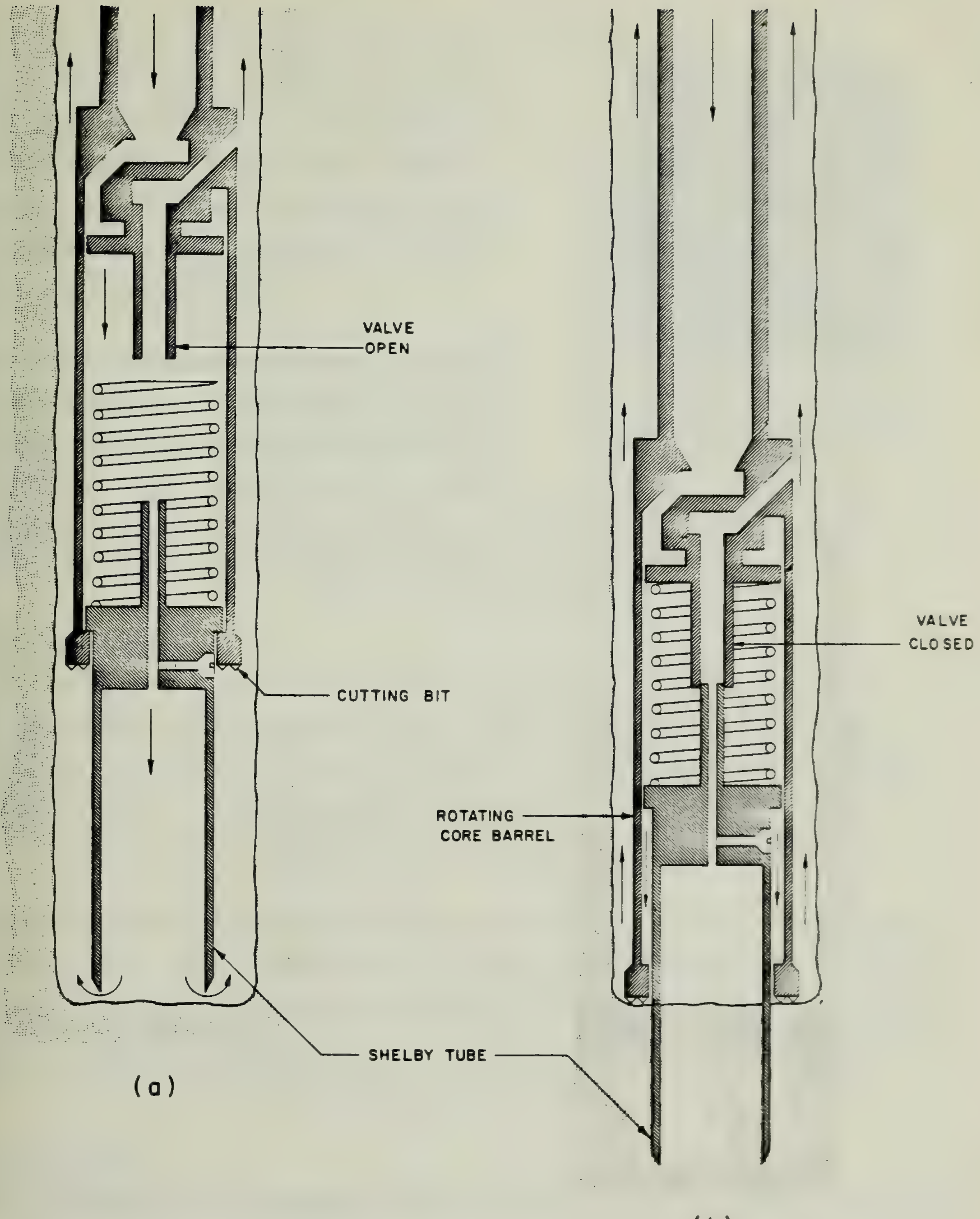
## FOR SOILS DIFFICULT TO RETAIN IN SAMPLER


DRIVING OR PUSHING MECHANISM
COUPLING
WATER OUTLETS
NOTCHES FOR ENGAGING FISHING TOOL
CHECK VALVES
NEOPRENE GASKET
HEAD
VALVE CAGE
SPLIT BARREL (TO FACILITATE REMOVAL OF CORE SAMPLE)
CORE-RETAINER RINGS (2-1/2" O.D. BY 1" LONG)
BIT
CORE-RETAINING DEVICE
RETAINER RING
RETAINER PLATES (INTERCHANGEABLE WITH OTHER TYPES)

NOTE:
"HEAD EXTENSION" CAN BE INTRODUCED BETWEEN "HEAD" AND "SPLIT BARREL"

## ALTERNATE ATTACHMENTS





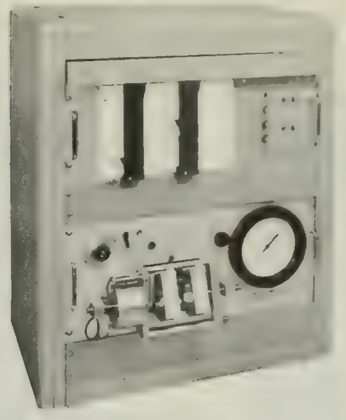
DIAGRAMMATIC SKETCH OF PITCHER SAMPLER

(a) SAMPLE TUBE SUSPENDED FROM CORE BARREL WHILE BEING LOWERED INTO HOLE.

(b) TUBE FORCED INTO SOIL AHEAD OF CORE BARREL.

## METHOD OF PERFORMING DIRECT SHEAR AND FRICTION TESTS

DIRECT SHEAR TESTS ARE PERFORMED TO DETERMINE THE SHEARING STRENGTHS OF SOILS. FRICTION TESTS ARE PERFORMED TO DETERMINE THE FRICTIONAL RESISTANCES BETWEEN SOILS AND VARIOUS OTHER MATERIALS SUCH AS WOOD, STEEL, OR CONCRETE. THE TESTS ARE PERFORMED IN THE LABORATORY TO SIMULATE ANTICIPATED FIELD CONDITIONS.



**DIRECT SHEAR APPARATUS WITH ELECTRONIC RECORDER**

EACH SAMPLE IS TESTED WITHIN THREE BRASS RINGS, TWO AND ONE-HALF INCHES IN DIAMETER AND ONE INCH IN LENGTH. UNDISTURBED SAMPLES OF IN-PLACE SOILS ARE TESTED IN RINGS TAKEN FROM THE SAMPLING DEVICE IN WHICH THE SAMPLES WERE OBTAINED. LOOSE SAMPLES OF SOILS TO BE USED IN CONSTRUCTING EARTH FILLS ARE COMPACTED IN RINGS TO PREDETERMINED CONDITIONS AND TESTED.

### DIRECT SHEAR TESTS

A THREE-INCH LENGTH OF THE SAMPLE IS TESTED IN DIRECT DOUBLE SHEAR. A CONSTANT PRESSURE, APPROPRIATE TO THE CONDITIONS OF THE PROBLEM FOR WHICH THE TEST IS BEING PERFORMED, IS APPLIED NORMAL TO THE ENDS OF THE SAMPLE THROUGH POROUS STONES. A SHEARING FAILURE OF THE SAMPLE IS CAUSED BY MOVING THE CENTER RING IN A DIRECTION PERPENDICULAR TO THE AXIS OF THE SAMPLE. TRANSVERSE MOVEMENT OF THE OUTER RINGS IS PREVENTED.

THE SHEARING FAILURE MAY BE ACCOMPLISHED BY APPLYING TO THE CENTER RING EITHER A CONSTANT RATE OF LOAD, A CONSTANT RATE OF DEFLECTION, OR INCREMENTS OF LOAD OR DEFLECTION. IN EACH CASE, THE SHEARING LOAD AND THE DEFLECTIONS IN BOTH THE AXIAL AND TRANSVERSE DIRECTIONS ARE RECORDED AND PLOTTED. THE SHEARING STRENGTH OF THE SOIL IS DETERMINED FROM THE RESULTING LOAD-DEFLECTION CURVES.

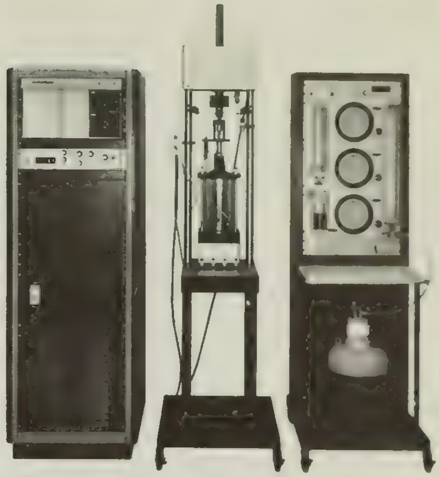
### FRICTION TESTS

IN ORDER TO DETERMINE THE FRICTIONAL RESISTANCE BETWEEN SOIL AND THE SURFACES OF VARIOUS MATERIALS, THE CENTER RING OF SOIL IN THE DIRECT SHEAR TEST IS REPLACED BY A DISK OF THE MATERIAL TO BE TESTED. THE TEST IS THEN PERFORMED IN THE SAME MANNER AS THE DIRECT SHEAR TEST BY FORCING THE DISK OF MATERIAL FROM THE SOIL SURFACES.

## METHODS OF PERFORMING UNCONFINED COMPRESSION AND TRIAXIAL COMPRESSION TESTS

THE SHEARING STRENGTHS OF SOILS ARE DETERMINED FROM THE RESULTS OF UNCONFINED COMPRESSION AND TRIAXIAL COMPRESSION TESTS. IN TRIAXIAL COMPRESSION TESTS THE TEST METHOD AND THE MAGNITUDE OF THE CONFINING PRESSURE ARE CHOSEN TO SIMULATE ANTICIPATED FIELD CONDITIONS.

UNCONFINED COMPRESSION AND TRIAXIAL COMPRESSION TESTS ARE PERFORMED ON UNDISTURBED OR REMOLDED SAMPLES OF SOIL APPROXIMATELY SIX INCHES IN LENGTH AND TWO AND ONE-HALF INCHES IN DIAMETER. THE TESTS ARE RUN EITHER STRAIN-CONTROLLED OR STRESS-CONTROLLED. IN A STRAIN-CONTROLLED TEST THE SAMPLE IS SUBJECTED TO A CONSTANT RATE OF DEFLECTION AND THE RESULTING STRESSES ARE RECORDED. IN A STRESS-CONTROLLED TEST THE SAMPLE IS SUBJECTED TO EQUAL INCREMENTS OF LOAD WITH EACH INCREMENT BEING MAINTAINED UNTIL AN EQUILIBRIUM CONDITION WITH RESPECT TO STRAIN IS ACHIEVED.



TRIAXIAL COMPRESSION TEST UNIT

YIELD, PEAK, OR ULTIMATE STRESSES ARE DETERMINED FROM THE STRESS-STRAIN PLOT FOR EACH SAMPLE AND THE PRINCIPAL STRESSES ARE EVALUATED. THE PRINCIPAL STRESSES ARE PLOTTED ON A MOHR'S CIRCLE DIAGRAM TO DETERMINE THE SHEARING STRENGTH OF THE SOIL TYPE BEING TESTED.

UNCONFINED COMPRESSION TESTS CAN BE PERFORMED ONLY ON SAMPLES WITH SUFFICIENT COHESION SO THAT THE SOIL WILL STAND AS AN UNSUPPORTED CYLINDER. THESE TESTS MAY BE RUN AT NATURAL MOISTURE CONTENT OR ON ARTIFICIALLY SATURATED SOILS.

IN A TRIAXIAL COMPRESSION TEST THE SAMPLE IS ENCASED IN A RUBBER MEMBRANE, PLACED IN A TEST CHAMBER, AND SUBJECTED TO A CONFINING PRESSURE THROUGHOUT THE DURATION OF THE TEST. NORMALLY, THIS CONFINING PRESSURE IS MAINTAINED AT A CONSTANT LEVEL, ALTHOUGH FOR SPECIAL TESTS IT MAY BE VARIED IN RELATION TO THE MEASURED STRESSES. TRIAXIAL COMPRESSION TESTS MAY BE RUN ON SOILS AT FIELD MOISTURE CONTENT OR ON ARTIFICIALLY SATURATED SAMPLES. THE TESTS ARE PERFORMED IN ONE OF THE FOLLOWING WAYS:

UNCONSOLIDATED-UNDRAINED: THE CONFINING PRESSURE IS IMPOSED ON THE SAMPLE AT THE START OF THE TEST. NO DRAINAGE IS PERMITTED AND THE STRESSES WHICH ARE MEASURED REPRESENT THE SUM OF THE INTERGRANULAR STRESSES AND PORE WATER PRESSURES.

CONSOLIDATED-UNDRAINED: THE SAMPLE IS ALLOWED TO CONSOLIDATE FULLY UNDER THE APPLIED CONFINING PRESSURE PRIOR TO THE START OF THE TEST. THE VOLUME CHANGE IS DETERMINED BY MEASURING THE WATER AND/OR AIR EXPELLED DURING CONSOLIDATION. NO DRAINAGE IS PERMITTED DURING THE TEST AND THE STRESSES WHICH ARE MEASURED ARE THE SAME AS FOR THE UNCONSOLIDATED-UNDRAINED TEST.

DRAINED: THE INTERGRANULAR STRESSES IN A SAMPLE MAY BE MEASURED BY PERFORMING A DRAINED, OR SLOW, TEST. IN THIS TEST THE SAMPLE IS FULLY SATURATED AND CONSOLIDATED PRIOR TO THE START OF THE TEST. DURING THE TEST, DRAINAGE IS PERMITTED AND THE TEST IS PERFORMED AT A SLOW ENOUGH RATE TO PREVENT THE BUILDUP OF PORE WATER PRESSURES. THE RESULTING STRESSES WHICH ARE MEASURED REPRESENT ONLY THE INTERGRANULAR STRESSES. THESE TESTS ARE USUALLY PERFORMED ON SAMPLES OF GENERALLY NON-COHESIVE SOILS, ALTHOUGH THE TEST PROCEDURE IS APPLICABLE TO COHESIVE SOILS IF A SUFFICIENTLY SLOW TEST RATE IS USED.

AN ALTERNATE MEANS OF OBTAINING THE DATA RESULTING FROM THE DRAINED TEST IS TO PERFORM AN UNDRAINED TEST IN WHICH SPECIAL EQUIPMENT IS USED TO MEASURE THE PORE WATER PRESSURES. THE DIFFERENCES BETWEEN THE TOTAL STRESSES AND THE PORE WATER PRESSURES MEASURED ARE THE INTERGRANULAR STRESSES.

# APPENDIX B

# ROUTE SELECTION BY COMPUTER MODELING (GIMS)

## B1.0 INTRODUCTION

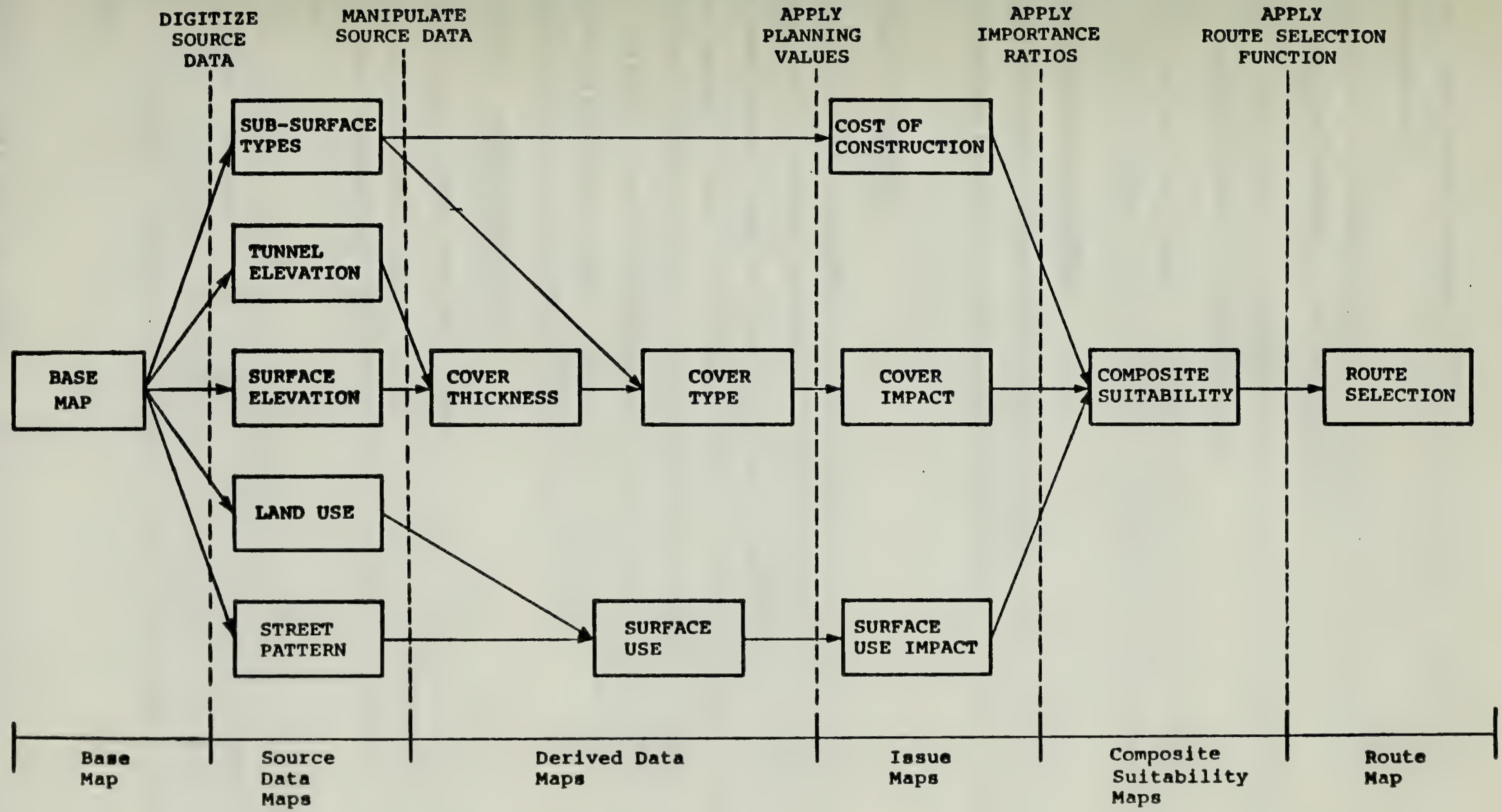
This Appendix presents the results of a study prepared by the Planning Systems Group of Dames & Moore to optimize route selection for the Richmond Transport Sewer tunnel. Section B2.0 includes descriptions of the methodology and the Geographic Information Management System (GIMS) used for our analysis. Section B3.0 outlines, step-by-step, all trial route analyses which led to the final route configuration shown on Plate B-1.

The objective of this task was to study route selection by a method known as overlay suitability mapping, described in this Appendix. It was expected that in approaching the problem of route selection from an entirely new direction, the results would either support or disqualify routes selected on the basis of the geotechnical investigation, thereby lending more "depth" or credibility to the final "best" route chosen. In general, the results of the GIMS analysis support the choice of the Preferred Route described in the main report of the geotechnical investigation.

## B2.0 METHOD OF ANALYSIS

### B2.1 General

The method of overlay suitability mapping involves first identifying the major issues of concern which influence the suitability of any particular route. Information (source data) required to define these issues is then chosen, and maps are prepared which show the geographical distribution of this source data. The various Source Data Maps can then be modified or combined as desired to produce what are called Derived Maps, directly depicting the selected issues of concern. At this point the many data catagories are "weighted" relative to their suitability for a tunnel route and the resulting maps are called Issue Maps. The Issue Maps are then combined by superposition to form a Composite Suitability Map and the computer, using a route selection function, computes the best route between given starting and ending points. A Data Structure Diagram showing the flow of data processing is presented on Figure 1.



DATA STRUCTURE DIAGRAM

FIGURE 1

The study team decided that there were three major issues of concern in this project:

1. Cost of Construction - estimated by the particular type and length of material to be penetrated.
2. Cover Impact - estimated from the type and thickness of the material over the tunnel crown.
3. Surface Use Impact - estimated from the sensitivity of the current surface land use to possible construction disturbance or damage.

## B2.2 Derivation of the Maps

The following sections describe the steps by which the GIMS method was used to reconcile each of these issues and produce a final "optimum" route path.

### B2.2.1 BASE MAP

To facilitate assignment of the various source data to their respective locations and to enable subsequent computer manipulation and combination of two or more maps, a base map was prepared by subdividing the study area into a great number of small rectangular cells. For convenience, advantage was taken of the regular pattern of city streets occurring over most of the study area. Cell size was approximately 100 feet square. Most streets were taken to be one cell wide; typical blocks were 2 cells wide by 6 cells long. All subsequent map types were prepared from this Base Map.

### B2.2.2 SOURCE DATA MAPS

Five source data maps were input to the geographic system. The source maps contain information on a cell-by-cell basis for subsurface soil or rock type, tunnel elevation,* ground surface elevation, land use, and street pattern.

The Subsurface Type Source Map presents major subsurface soil or rock types at the elevation of the proposed tunnel. Borings performed during this project and existing maps by Dames & Moore provided the source data. The types of subsurface materials mapped were rock, Colma sand, dune sand, and melange.

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*Elevations refer to the City and County of San Francisco Datum, which is 8.616 feet above Mean Sea Level.

The Tunnel Elevation Source Map contains the elevation of the proposed tunnel at its invert and was produced using information provided by the City and County of San Francisco. Every cell was given an elevation which represented the tunnel invert elevation if the tunnel were to pass through that cell, based upon a fixed tunnel elevation of zero at its western terminus and a constant upward gradient of 0.002.

The Surface Elevation Source Map contains elevation data gathered from topographic contours. The contours were taken from maps provided by the City and County of San Francisco and by the San Francisco Division of Beaches and Parks. Each cell was given an elevation which is representative of the true surface elevation at that location in the study area.

The Land Use Source Map contains general land use data gathered by the City and County of San Francisco on a community area land use study produced in 1974. The types of land use mapped were:

1. City parks
2. Golden Gate National Recreation Area
3. Fort Miley Park
4. Palace of the Legion of Honor
5. Presidio
6. Residential/light commercial
7. Schools
8. Fort Miley Veterans Hospital
9. Restricted bluff zones

The Street Data Source Map contains the general street patterns. The data were taken from the community area land use study provided by the City and County of San Francisco.

### B2.2.3 DERIVED DATA MAPS

Derived data maps represent intermediate steps in the data manipulation process which are necessary to obtain maps for the Issues of Concern. No grading or weighting of these data has been input into the system at this stage. Three maps were derived from the source maps as shown on the Data Structure Diagram, Figure 1: cover thickness, cover type, and surface use.

The Cover Thickness Map was derived by subtracting the Tunnel Elevation Source Map from the Surface Elevation Source Map, cell by cell, allowing for the diameter of the tunnel. The resulting map shows the cover thickness over the crown of the tunnel. Five ranges of thickness were mapped: 0-15', 15-30', 30-60', 60-120', 120-500'.

The Cover Type Map was derived by combining the Subsurface Type Source Map and the derived Cover Thickness Map. The Cover Type Map contains 20 data categories which represent all combinations of the 4 subsurface soil and rock types and the 5 cover thickness ranges.

The Surface Use Map was derived by combining the Land Use and Street Pattern Source Maps.

### B2.2.4 ISSUE MAPS

Maps for the three issues of concern were next produced from their respective source map or derived map by assigning planning values to each data catagory shown on the maps. These planning values ranged from 1 (most suitable) to 9 (least suitable). Planning values were selected by the Dames & Moore project team with input from the Sanitary Engineering Staff of the City and County of San Francisco. Planning values do not rate the various data catagories in order of importance, but rather each data catagory was rated independently for suitability for the tunnel route. Thus, different data catagories on a particular issue map may have the same planning value. For instance, on the Surface Use Issue Map, schools, hospitals and residential areas were each given a planning value of 9.

### B2.2.5 COMPOSITE SUITABILITY MAPS

The three issue maps were then combined by summation, cell by cell, to produce a Composite Suitability Map. Before adding issue maps, each issue map as a whole was weighted with an importance ratio. The importance ratio is a multiplier applied to the planning value in each and every cell of an issue map.

GIMS allows the user to easily alter the weights (planning values and importance ratios) and produce new Composite Suitability Maps. It gives the decision-maker the flexibility to test the sensitivity of different weighting schemes against the resulting changes in route alignment. In this project, 11 different weighting schemes were tested as shown in Figure 2.

The first weights (planning values and importance ratios) were selected by the Dames & Moore project team. These weights formed a basic set of decisions from which alternate weighting schemes could be compared. With the exception of altering the weights to test the sensitivity of the data and minor adjustments of the weights on the surface use issue, the weights on the initial run were very close to those used for the final route selection.

### B2.3 ROUTE SELECTION

The route selection function has the ability to find the least impact or least costly route between fixed starting and ending points on a Composite Suitability Map. If one visualizes each of the issue maps as a "topographic" map where "most favorable" cells having low values are thought of as valleys and "least favorable" cells with their high values are thought of as hills, when several issue maps are combined to form a Composite Suitability Map, a new "surface" of "hills and valleys" will be formed. The route selection function then computes the path of least resistance by attempting to stay in "valleys" and cross as few "hills" as possible to arrive at the lowest cumulative total resistance. Of course the total length of the route is important as well as the number of "hills" to be crossed. The function utilizes a spatial analysis technique to compute the best, the next best, the next best, etc., route through the Composite Suitability Map.

The function was applied to each of the 11 Composite Suitability Maps produced during the course of this study. The final Composite Suitability/ Route Selection Map is shown on Plate B-1. This map is the result of Trial Run No. 11 as discussed in the next section, and uses the planning values and importance ratios shown on Figure 2 for Trial 11. To help evaluate Plate B-1 and illustrate the contribution of the different issues of concern, the route selection function was also applied to the Surface Use Issue Map by itself (Trial 10, Figure 2) and the results are presented on Plate B-2. Additionally, the Cost of Construction and Cover Impact Issue maps were combined without the Surface Use Issue Map (Trial 9, Figure 2). The resultant composite map is called Engineering Factors and Plate B-3 shows the results of applying the route selection function to this scheme.

## B3.0 TRIAL ANALYSES FOR ROUTE SELECTION

This section describes the input weighting values and results of each trial route selection listed on Figure 2. Trials 1 through 8 were used to select the weighting values for the final three composite suitability maps.

B3.1 Trial 1. The project team of Dames & Moore carefully deliberated this initial weighting scheme, and as can be seen from the minor changes in the weights used for the other trials, the values chosen were quite appropriate. The east portal is at the boundary of the Presidio on El Camino del Mar Street, and the west portal is at the intersection of Fulton Street and the Great Highway. Starting from the east portal, the computed route corridor headed due west going on either side of the Palace of the Legion of Honor and staying north of the Veterans Hospital. The route then headed in a southwest direction to the Great Hightway, then due south to the west portal at Fulton Street. This northerly route was due mainly to the corridor attempting to stay in the rock and away from the residential areas.

B3.2 Trial 2. The project team then decided to test the sensitivity of the weights in regard to forcing the tunnel to take a diagonal straight line path between the east and west portals. To do this, an importance ratio of 2.0 was applied to the cost of construction issue in an attempt to have it override the influence surface use issue. The route continued to go in a due westerly direction from the east portal and then south down the Great Highway to the west portal.

B3.3 Trial 3. Routes 1 and 2 were deemed to be significant but it was decided that some fine tuning could take place. To evaluate the sensitivity of the planning value assigned to the streets, an attempt was made to force the corridor south of the Veterans Hospital and through some of the streets. To this end, the planning value assigned to the streets was lowered from five to three. The results were insignificant because the corridor still took a due westerly direction from the east portal, stayed above the Veterans Hospital, and then went due south down the Great Highway to the west portal.

B3.4 Trial 4. It was next decided to test the sensitivity of the importance ratio applied to the cost of construction issue. The importance ratio was raised from one to five, and the planning value applied to the streets was returned to five. It was thought that a more direct, straight line

| ISSUE MAP with component data categories | TRIAL 1 | TRIAL 2 | TRIAL 3 | TRIAL 4 | TRIAL 5 | TRIAL 6 | TRIAL 7 | TRIAL 8 | TRIAL 9 | TRIAL 10 | TRIAL 11 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COST OF CONSTRUCTION | 1.0 | 2.0 | 1.0 | 5.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | | 1.0 | Importance Ratio |
| Rock | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | | 4 | Planning Values |
| Colma Sand | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | | 5 | |
| Dune Sane | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | | 6 | |
| Melange | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | | 4 | |
| COVER TYPE IMPACT (Depth of Cover) Feet | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | | 1.0 | Importance Ratio |
| Rock 0-15 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | | 7 | Planning Values |
| Rock 15-30 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | | 5 | |
| Rock 30-60 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | | 3 | |
| Rock 60-120 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | |
| Rock 120-500 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | |
| Colma 0-15 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | | 9 | |
| Colma 15-30 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | | 7 | |
| Colma 30-60 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | | 5 | |
| Colma 60-120 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | | 4 | |
| Colma 120-500 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | | 3 | |
| Dune 0-15 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | | 9 | |
| Dune 15-30 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | | 8 | |
| Dune 30-60 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | | 7 | |
| Dune 60-120 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | | 5 | |
| Dune 120-500 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | | 4 | |
| Melange 0-15 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | | 7 | |
| Melange 15-30 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | | 5 | |
| Melange 30-60 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | | 3 | |
| Melange 60-120 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | |
| Melange 120-500 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | |
| SURFACE USE IMPACT | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | | 1.0 | 1.0 | Importance Ratio |
| City parks | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | 1 | Planning Values |
| GGNRA | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | 1 | |
| Fort Miley park | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | 1 | |
| Palace of Legion of Honor | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | | 5 | 5 | |
| Presidio | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | 1 | |
| Streets | 5 | 5 | 3 | 5 | 3 | 3 | 1 | 3 | | 1 | 1 | |
| Residental/Comm | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | | 9 | 9 | |
| Schools | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | | 9 | 9 | |
| Veterans Hospital | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | | 9 | 9 | |

NOTE: Assigned weights range from 1 (most favorable) to 9 (least favorable)

WEIGHTING SCHEMES USED FOR EACH TRIAL RUN

FIGURE 2

corridor would result and this was indeed the case. The route headed west from the east portal, then it shortly took a straight line diagonal path to the west portal. The importance of this trial was to show that the cost of construction issue had to be raised to an unrealistically high weight in order to force the alignment into a near straight-line diagonal corridor.

B3.5 Trial 5. The position of the east portal was not fixed at the boundary of the Presidio on El Camino del Mar Street, so the project team decided to move the portal to another location to see if the tunnel alignment would alter. The east portal was moved to the intersection of Lake Street and 26th Avenue. The importance ratio on the cost of construction issue was returned to 1.0 and the planning value on the streets was put at 3.0. The computed alignment of the corridor was not affected for it still took a due westerly route above the Veterans Hospital and then due south to the west portal.

B3.6 Trial 6. For the remainder of the route selection, the east portal was returned to its position at the boundary of the Presidio on El Camino del Mar Street. The project team then investigated why the corridor was staying north of the Veterans Hospital. Investigations uncovered the fact that there was a 300-foot-wide open strip of land to the south of the hospital buildings which had been classified the same as the buildings of the hospital. The high planning value assigned to this strip of land did not permit the route to go between the hospital and the residential areas south of Clement Street. To correct this situation, a narrow corridor just south of the Veterans Hospital was given a more suitable planning value of 1.0, which was the same as the planning value assigned to Fort Miley Park which surrounds the Veterans Hospital. This time, the computed alignment corridor again headed wast from the east portal but went south of the Palace of the Legion of Honor and south of the Veterans Hospital, before turning due south toward the west portal.

B3.7 Trial 7. The City and County of San Francisco's engineering staff pursuaded the team to alter the weight given to the streets. Because the streets are City property and are thus very suitable for the tunnel alignment, the streets were put at the most suitable planning value, 1.0. The

computed alignment again headed west from the east portal, below the Palace of the Legion of Honor, below the Veterans Hospital, and through certain streets in a zigzag southwest direction towards the west portal.

B3.8 Trial 8. After reviewing all of the previous 7 routes, the project team was basically satisfied with the general orientation the corridors were taking. Most of the corridors were along the Great Highway or La Playa Street just above the west portal. This fact lead the project team to experiment with an optional location of the southern portal. This was justified by assuming that the tunnel could be constructed by open-cut for several blocks north of the original west portal. The west portal was therefore moved to the intersection of Balboa and La Playa Streets, and the planning value on the streets returned to 3.0. There was no significant change in the computed corridor alignment and thus it was apparent that a modification in either the west or east portal location had little effect on the alignment of the corridor.

B3.9 Trial 9. At this point, the project team decided that the final corridor alignments could be selected. At a meeting with the Dames & Moore project team and the staff from the City and County of San Francisco, it was decided that three final routes would be processed. The first route would consider only the engineering factors. The engineering factors are the cost of construction issue and the cover impact issue. Without the surface use issue, the computed corridor alignment again headed west from the east portal but soon took a straight-line diagonal course to the west portal, keeping in rock as much as possible. The corridor did not head farther west below the Veterans Hospital because the residential considerations on the surface use impact issue were not applied to this route. This route is shown on Plate B-3, Route Selection/Engineering Factors.

B3.10 Trial 10. To evaluate what the corridor alignment would be if the surface use impact issue was considered separately, a route function was run without the cost of construction and cover type impact issues considered. The computed route again took a western orientation from the east portal but soon began to weave through the streets in a southwest orientation toward the west portal. This route is shown on Plate B-2, Route Selection/Surface Use Factors.

B3.11 Trial 11. To consider the engineering factors and surface use factors together in a composite route, the eleventh and final route was processed. The importance ratio on each issue map was 1.0, the east portal was at the Presidio boundary on El Camino del Mar Street, and the west portal was at the intersection of Fulton Street and the Great Highway. The computed corridor again headed west from the east portal through Lincoln park, below the Veterans Hospital and through certain streets in a southwest direction toward the west portal. This is the final corridor alignment shown on Plate B-1, Route Selection/Composite Suitability.

The following Plates are attached to and complete Appendix B of this report:

Plate B-1 - Route Selection, Composite Suitability
Plate B-2 - Route Selection, Surface Use Factors
Plate B-3 - Route Selection, Engineering Factors

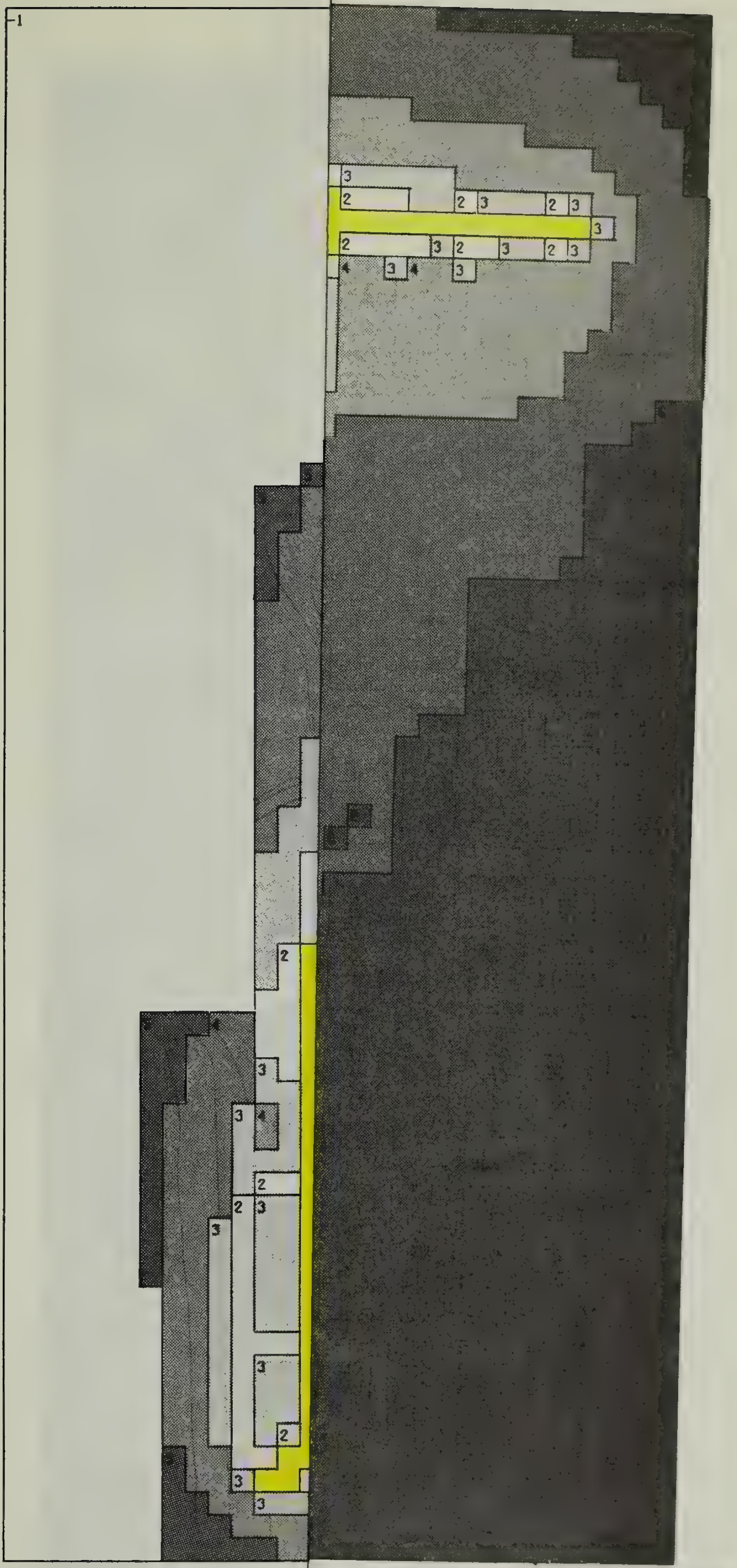

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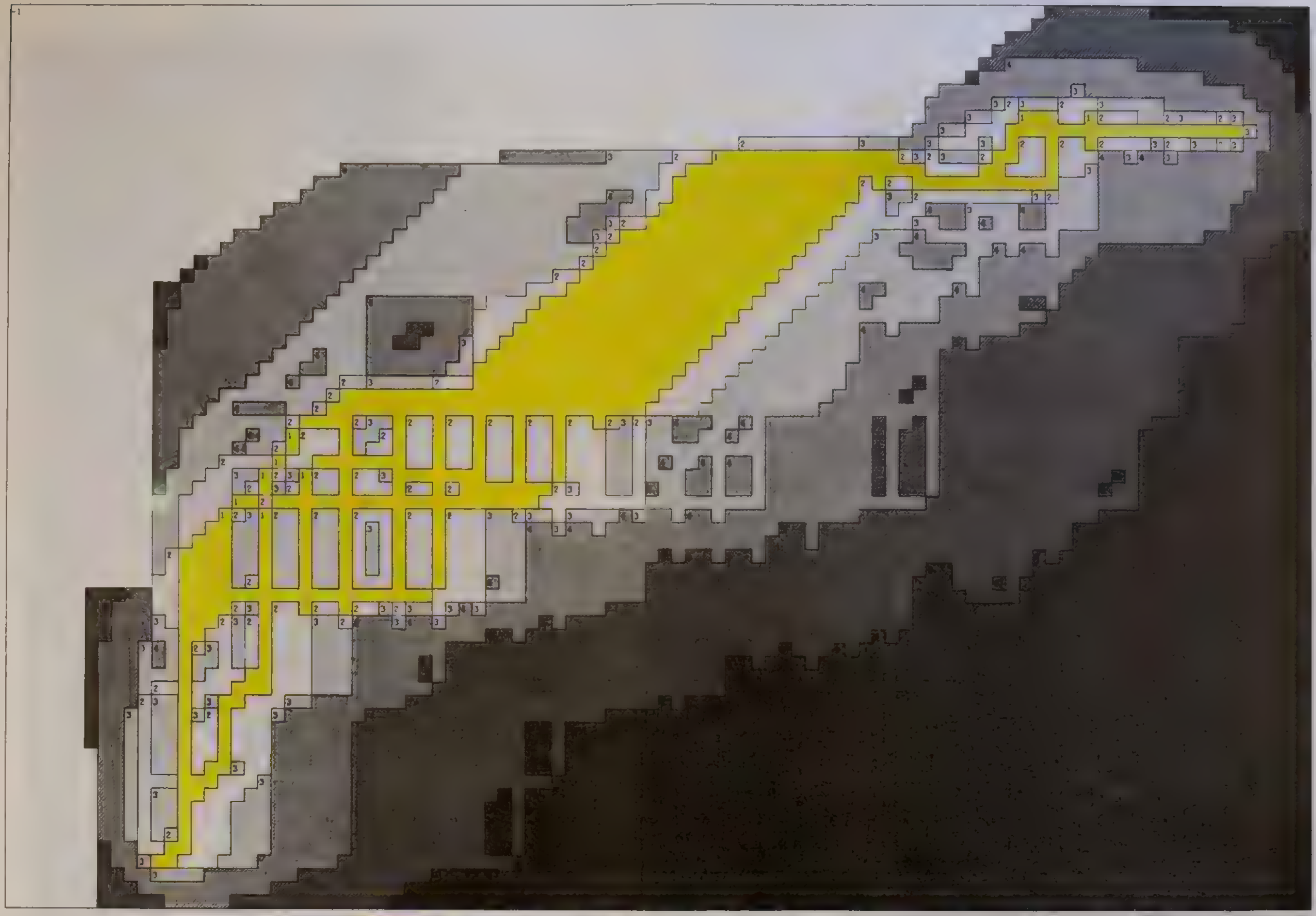
PLATE B-1



# ROUTE SELECTION COMPOSITE SUITABILITY

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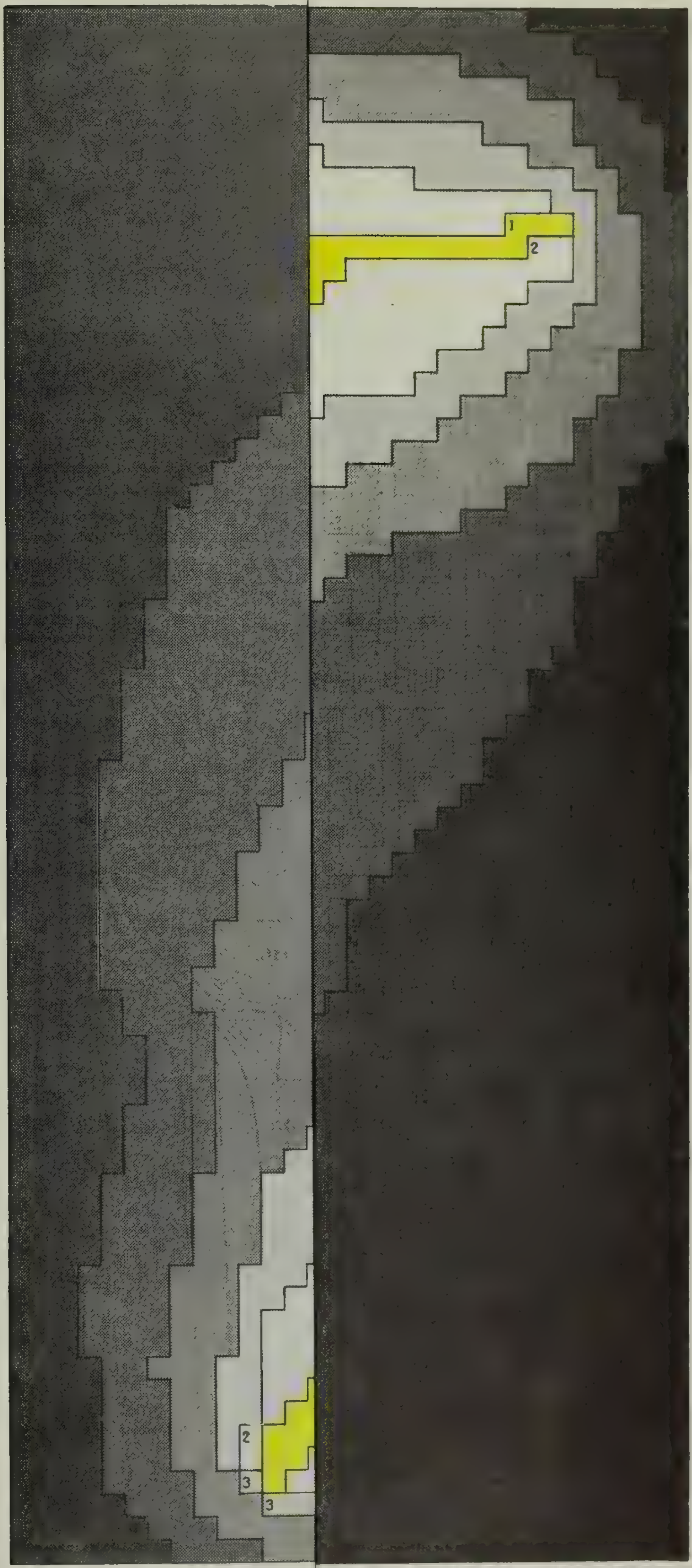

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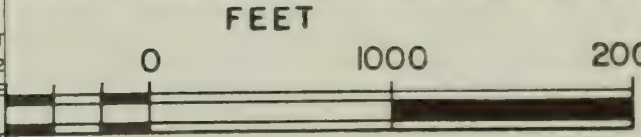

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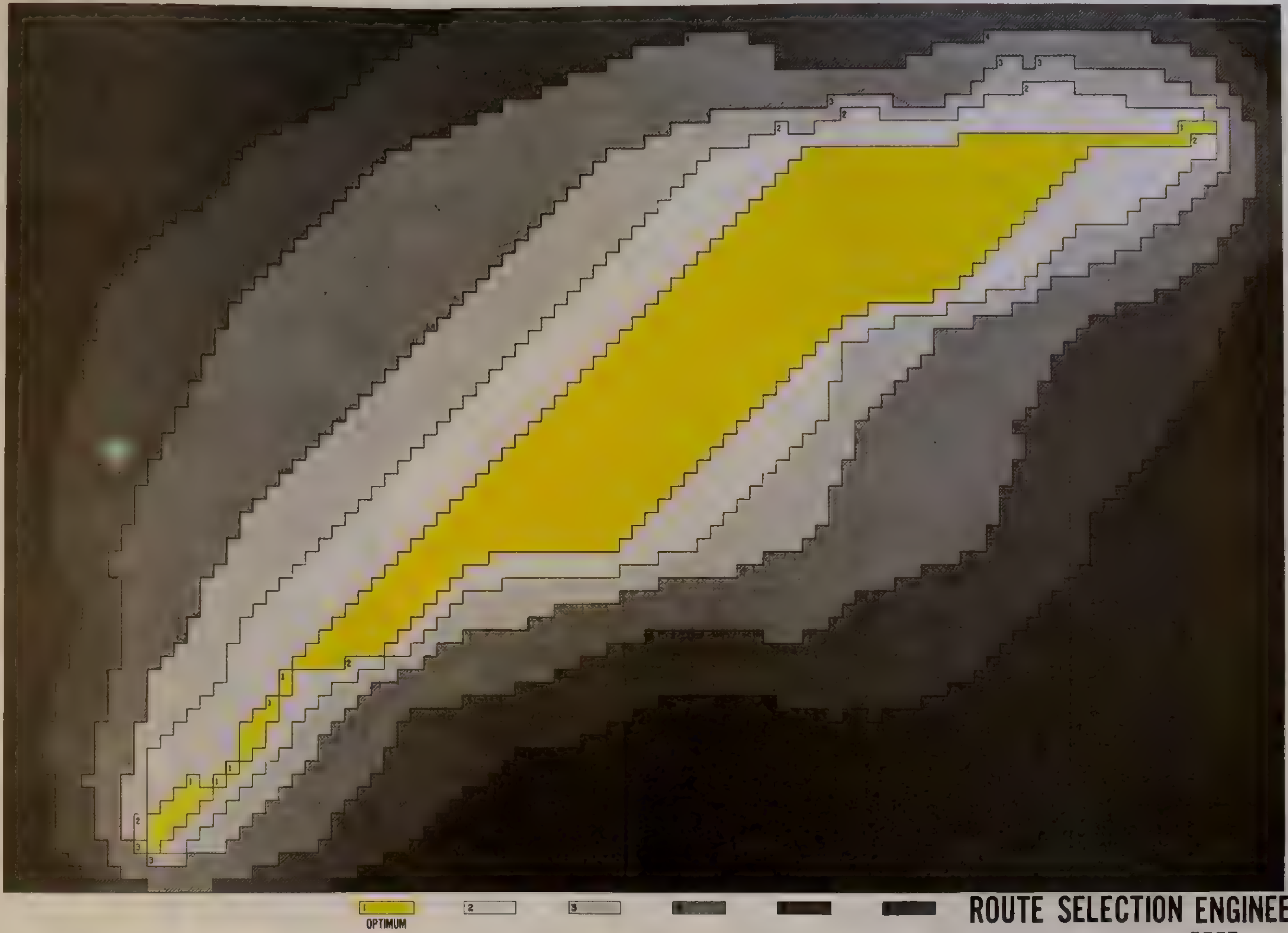
PLATE B-3



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# ROUTE SELECTION ENGINEERING FACTORS

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PLATE B-3

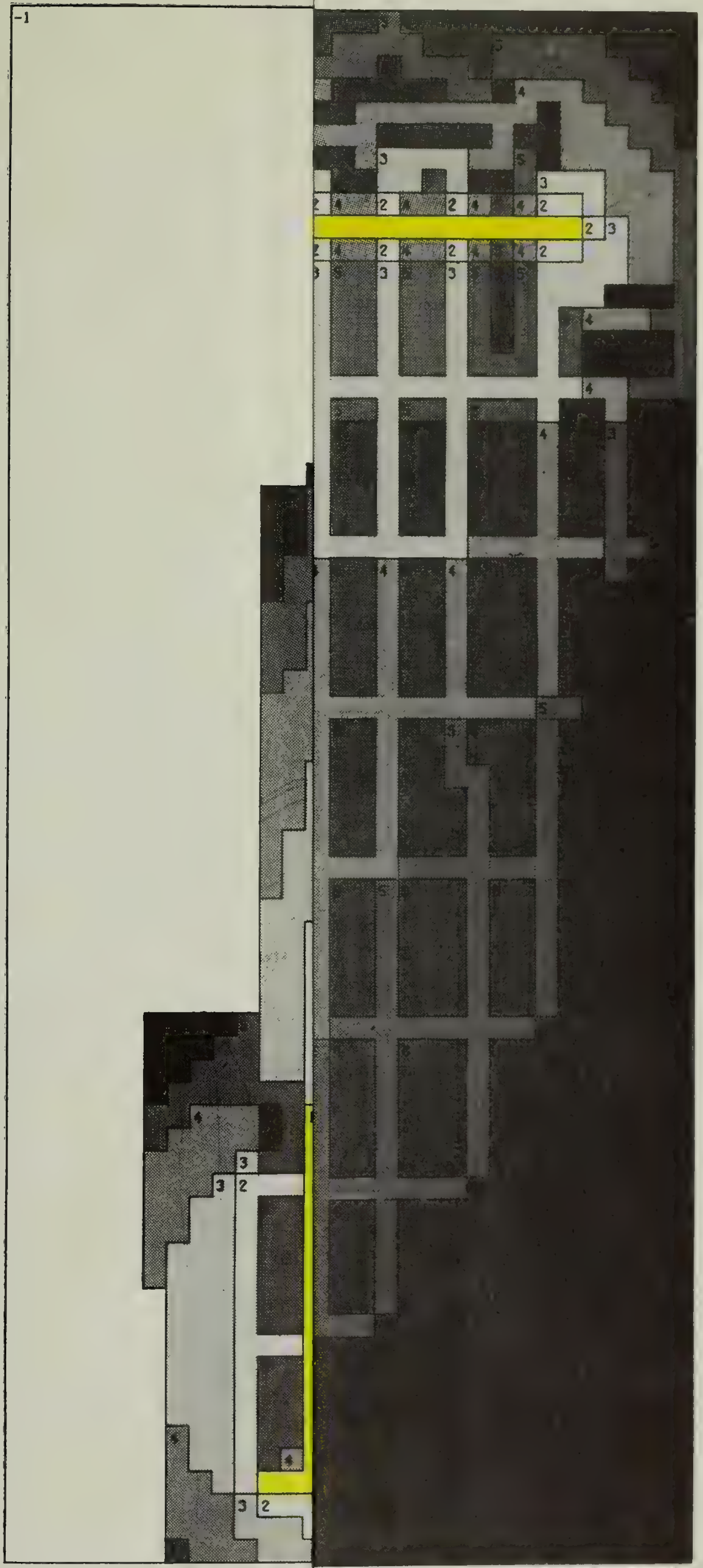

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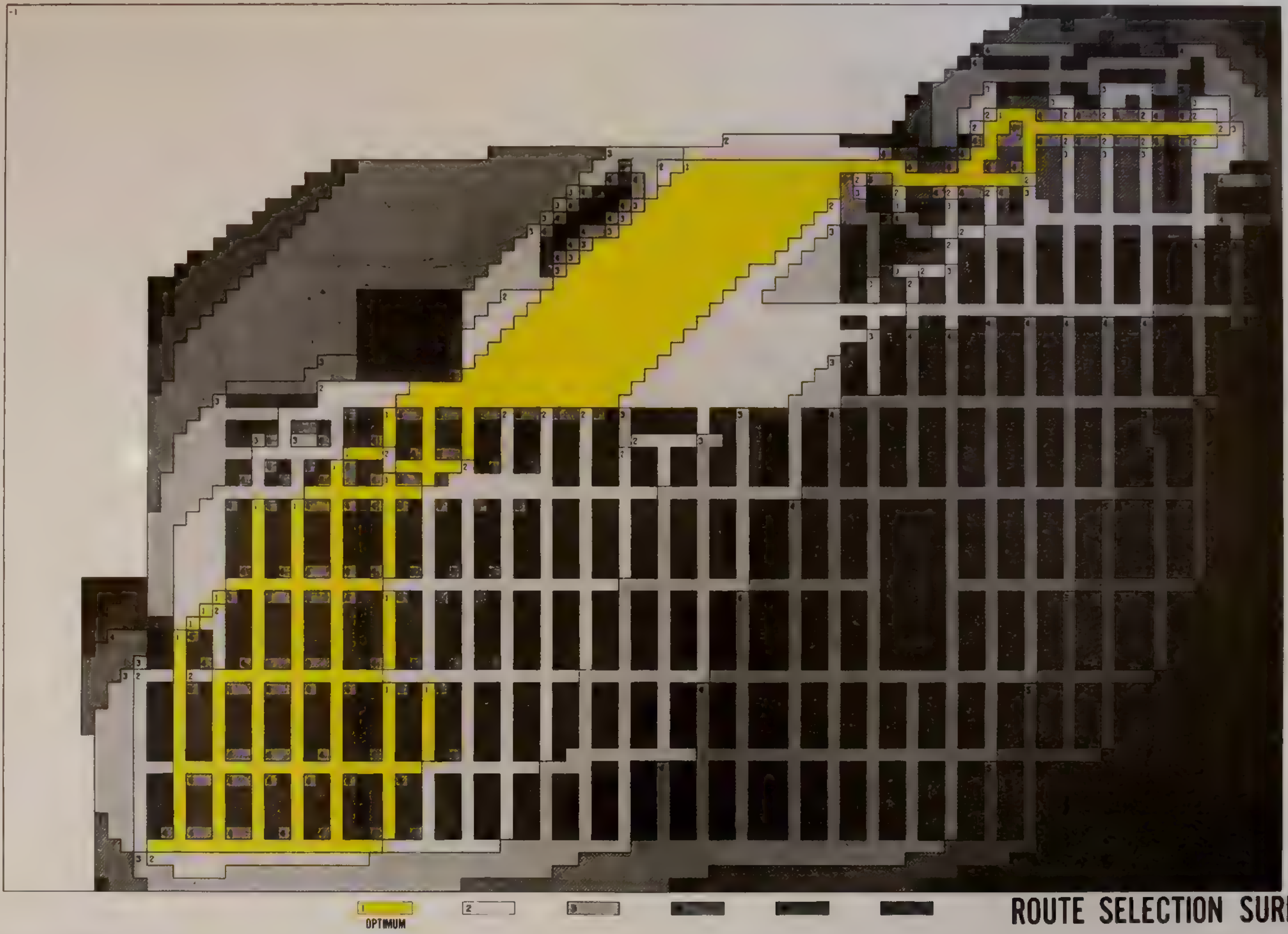
PLATE B-2



# ROUTE SELECTION SURFACE FACTORS

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DAMES & MOORE

PLATE B-2

# RICHMOND TRANSPORT SEWER

## CONSTRUCTION FEASIBILITY PRELIMINARY COST ESTIMATES

Submitted to
Dames & Moore

by

**PBQ & D, INC.**

FEBRUARY, 1979

# RICHMOND TRANSPORT SEWER
# CITY AND COUNTY OF SAN FRANCISCO

## CONSTRUCTION FEASIBILITY
## PRELIMINARY COST ESTIMATES

Prepared

For

DAMES & MOORE

By

PBQ&D, INC.

February, 1979

Parsons
Brinckerhoff

**Parsons Brinckerhoff International, Inc.** Engineers • Architects • Planners

February 21, 1979

Mr. Joseph Jeno
Dames and Moore
500 Sansome Street
San Francisco, CA 94111

Dear Mr. Jeno:

Transmitted herewith is our report on the construction feasibility and preliminary construction cost estimates of the tunnel alignments for the Richmond Transport Sewer Project for the City and County of San Francisco.

The submittal summarizes and completes our work under Task 6.7, Scope and Task Description, attachment II of our Agreement dated March 9, 1978.

We trust that this report will be helpful in the selection and analysis of the preferred tunnel alignment.

Very truly yours,

PBQ&D, Inc.

E Altshuler

E. Altshuler
Project Manager

EA/jc
encl.

**Mailing Address**
**165 Post Street • San Francisco, California 94108 • 415-986-2929 •** Cable: Parklap, San Francisco • Telex WU3-4763

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FIGURES (APPENDED)

Figure 1: Study Alignments

Figure 2: Main Collector Sewers

# 1. INTRODUCTION

## 1.1 Purpose and Scope

The City of San Francisco desires to construct a transport sewer from the Richmond District to a point near the intersection of Fulton Street and the Great Highway. The project is named the Richmond Transport Sewer Tunnel.

This report presents an assessment of the feasibility of constructing the Transport Tunnel along three basic alignments, herein named the Direct Route, the Southern Route, and the Northern Route. An alternate to the Northern Route is also examined. Comparative costs are included, anticipated construction problems are discussed, and impacts of construction on the neighboring communities are identified.

The alignments examined are shown on the Plan, Figure 1. One suitable study alignment was selected jointly by PBQ&D, Inc. and Dames & Moore along each of three corridors defined by Dames & Moore. Our study is based on personal field observations and geotechnical data presented in Dames & Moore's Phase II (Preliminary) Report, Geotechnical Investigation, for the Richmond Transport Sewer, dated Oct. 17, 1978, as well as on certain data made available to us since that date, specifically with regard to the Northern Route.

The preferred alignment is the Northern Route Alternate to Lobos Creek at Lincoln Boulevard. The original concepts considered the construction of a deep shaft at the intersection of Lake Street and 26th Avenue connecting with a new sewer in Lake Street, both of which would be unnecessary with the preferred alignment.

Scheduling of construction of the alternate Northern Route is briefly discussed herein. This report also considers the effects of selecting a tunnel diameter smaller than the 15-foot diameter assumed at the outset. Variations in tunnel diameter will not affect the relative advantages or disadvantages of the several alignments. Cost estimates shown herein for smaller diameter tunnels are not as accurate as those for the larger tunnel.

## 1.2 Study Alignments and Other System Components

The components of the basic system under study are shown on the Plan, Figure 1, and include (a) the Lake Street Sewer, from 17th Avenue to 26th Avenue, Point A to Point B on the Plan; (b) a drop shaft at Point B; and (c) the Richmond Transport Sewer Tunnel, from the drop shaft to a location near the intersection of the Great Highway and Fulton Street, Point F on the Plan. A pressure line, leading from Seacliff Pump Station No. 2 to Point B, would complete the system.

The three basic alignments considered for the Transport Sewer Tunnel between Point B and Point F are described briefly below (lengths do not include the Lake Street Sewer):

- The Direct Route is about 8,900 feet long and the shortest of the alternatives. This alignment runs diagonally through the residential area and follows nearly a straight line between Points B and F.
- The Southern Route is about 12,200 feet long and is the longest of the study alignments. This alignment runs along 26th Avenue to Point E, at Fulton Street, then westerly along Fulton Street to Point F.
- The Northern Route is about 10,000 feet long. This alignment runs North from Point F along the Great Highway to Point D North of Balboa Street, then in a east-northeasterly direction to Point B.

The inside diameter of the sewer is assumed to be 15 feet for all three alignments. The sewer is assumed to be concrete lined, using precast segments or cast-in-place concrete, depending on the alignment selected. At Point F, the invert is near elevation 0, and at point B, the invert is between elevation 18 and 25 (*). The gradient is approximately 0.002.

The drop shaft at Point B is assumed to be approximately 5 feet in diameter; it will carry sewage from the Lake Street Sewer and the Seacliff Pump into the Richmond Transport Sewer. The shaft would be about 120 feet deep.

Along Lake Street, from Point A at 17th Avenue to Point B at 26th Avenue, a new sewer line is proposed. The inside diameter at 17th Avenue and 26th Avenue will be 9.5 and 11 feet, respectively. The pressure line from Seacliff Pump No. 2 to the top of the drop shaft at Point B will be a small diameter line. The drop shaft, the Lake Street Sewer, and the pressure line are common to all three basic alignments.

The alternate to the Northern Route is nearly identical to the Northern Route alignment described above, along the western half of the alignment. The tunnel would, however, begin at Point C near the culvert carrying Lobos Creek under Lincoln Boulevard, then run beneath Camino Del Mar to 28th Avenue, and from there go directly to Point D at the Great Highway. The total length of this alignment, from Point C to Point F, is approximately 11,100 feet. The Lake Street sewer and drop shaft would not be part of this alternative.

(*) Datum base: City and County of San Francisco Datum, MSL+8.616'.

## 2. LAKE STREET SEWER AND DROP SHAFT

### 2.1 Proposed Sewer

The original alignment concept, involving a new sewer along Lake Street from 17th to 26th Avenue (Points A and B on Fig. 1), would require the opening of Lake Street and cause considerable disruption during construction. The preferred alignment avoids these problems.

The Lake Street Sewer would connect with the Transport Sewer Tunnel through a drop shaft at Point B; it would vary in diameter from 9.5 feet to 11 feet from Point A to Point B. The drop shaft is assumed to be 5 feet in diameter.

These structures would be common to the three basic alignments and are discussed separately in the following.

### 2.2 Geologic Conditions

Street elevation is between 114 and 120 between 17th and 24th Avenues, but rises to about 142 at 26th Avenue. Dune sands reach from the surface to below elevation 60. The groundwater table is generally below elevation 70 but rises to elevation 85 at 17th Avenue.

At the drop shaft, dune sands reach a depth of 90 feet (elevation 50) followed by sands of the Colma Formation. Groundwater here is at about elevation 70.

The dune sands are typically well sorted and relatively dense. They are uniform, cohesionless and pervious. The Colma Formation sands, on the other hand, are generally silty or clayey and, therefore, somewhat cohesive and much less pervious than the dune sands. Layers or pockets within this formation, however, lack cohesion and may be as pervious as the dune sands.

### 2.3 Construction

Construction of the Lake Street Sewer is significantly affected by the existing sewer utilities in this street. These are shown on Fig. 2. A 6'-6" overflow outfall runs north from Lake Street in 17th Avenue. A 5'-6" circular brick sewer runs from 17th Avenue to an overflow structure at 22nd Avenue, at elevation 98.6. A 6' circular brick sewer picks up flow from the South at 22nd Avenue, runs two blocks west along Lake and turns North at 24th Avenue, with an invert elevation of 95. A sewer tunnel 4'x6'-6" starts with a drop structure at 24th, runs two blocks West along Lake and turns in a southwesterly direction. The invert elevation is at or just above elevation 88.

To avoid interference with these sewers, it has been proposed that the new sewer be constructed as a mined tunnel under Lake Street located below the sewers. It is assumed that the sewers cannot be taken out of service long enough to allow replacement type construction.

At a reasonably safe 15 feet clear vertical distance between tunnel and overlying sewers, the tunnel invert elevation at 26th Avenue should be near elevation 60. The resulting invert elevation at 17th Avenue would be about 70. At these elevations, pre-construction dewatering would be required throughout for safe tunneling in the dune sands. A construction shaft for tunneling at either end would disrupt traffic on Lake Street for the duration of construction. Some damage to the existing sewers due to tunnel construction settlements could be expected.

Alternatively, a new sewer line along Lake Street could be constructed in open cut, adjacent to the existing sewers. A northern location appears to offer the least amount of interference. An invert elevation of about 100 at 17th Avenue dropping gradually to elevation 90 ± would allow laterals and other inflows to enter the line.

Construction would involve a braced trench about 30 feet deep most of the way, but up to 50 feet deep near 26th Avenue, and would be in sands above the water table. Though feasible, this is a deep trench, and construction would be difficult and expensive. Construction would partially block the street and probably prevent two-way traffic in the construction zone.

The Lake Street sewer should be constructed after completion of the Transport Tunnel between Points B and F, and the drop structure. Beginning at the drop structure, the sewer could be completed incrementally, and the connections made to existing sewers one by one in an easterly direction. The details and scheduling of this construction procedure can be determined only after a careful study of all the existing facilities. The drop shaft at 26th Avenue should be located away from the street intersection to minimize traffic interference.

Both of the methods considered for the Lake Street Sewer construction are disruptive to the community, expensive and difficult. The problems of constructing a new Lake Street Sewer can be avoided entirely if the preferred Lobos Creek alternative is adopted.

## 3. THE DIRECT ROUTE

### 3.1 Alignment and Geology

This alignment follows a nearly straight line from Point F at the Great Highway and Fulton Street to Point B at Lake Street and 26th Avenue.

A perfectly straight line (8,700 feet long) between these two points would carry the tunnel through two separate segments of bedrock and mixed-face conditions, with the remainder of the tunnel in soil. The groundwater table in the soil segments could be as high as 160 feet above the tunnel crown.

A slight bow to the South, as shown on the Plan, would increase the length by about 200 feet but probably eliminate one rock and mixed-face segment and bring the maximum head of water in the soil segments down to about 130 or 140 feet. This alignment has been the basis for the present study. The selection of a final alignment for this alternative would require additional explorations at critical points.

Tunnel construction would begin at Point F in dune sands, with groundwater at elevation 5. After about 2,000 feet, the tunnel would enter the Colma Formation, with groundwater at about elevation 45, 25 feet above the crown. Mixed face conditions would be encountered for 150 to 200 feet after about 4,200 feet of tunneling, and the next 2,500 feet of tunneling would be in rock of the Franciscan Formation.

Again, 150 to 200 feet of mixed-face tunneling would be encountered, followed by about 1,800 feet of tunneling in sands of the Colma Formation.

At the mixed-face segments on both sides of the rock tunnel, groundwater would be 130 to 140 feet above the crown.

The Franciscan bedrock is overlain by several feet of relatively impervious colluvium of some strength. The Franciscan rock is primarily a highly fractured sandstone but some siltstones and shales, serpentine, graywacke and chert may also be expected. The rock is expected to be generally competent and relatively impervious along most of the alignment. However, shear zones may be expected to have little strength and high permeability.

### 3.2 Portal at Fulton Street and the Great Highway

North of Fulton Street, block 1692 between La Playa and the Great Highway is vacant at present. A Safeway store occupies the adjacent block between 48th Avenue and La Playa. South of Fulton Street, the Golden Gate Park extends to the Great Highway.

The vacancy of block 1692 provides the opportunity to avoid interrupting traffic on Fulton Street for tunnel portal work. Assuming that the lot will be

available to the contractor during the time of construction, it will be well suited as a contractor's yard. The tunnel portal and a haul ramp may be built as temporary features within this block.

Alternatively, should this block not be available, a portal location adjacent to Fulton Street, within the Golden Gate Park, may be used as a temporary construction and portal area. Measures to minimize the impact of construction on the Park and its users may include environmentally acceptable fencing and shielding, and a careful layout of construction facilities to avoid removal of more than a minimum number of trees. The affected portion of the Park would be restored.

The substantial width of the Great Highway could also allow the portal and work area to be located within this street.

In the contractor's yard and work area, space and provisions are required for storage of both soil and rock tunnel equipment and material, equipment for transferring loads of excavated material from muck cars to trucks, and compressed air plant and appurtenances. Offices, change house, workshop and other amenities must also be provided.

The lowest portion of the haul ramp, adjacent to the tunnel portal, is several feet below the groundwater table and must be kept dry by suitable dewatering methods.

The location and construction features of the connection to the West Side Transport Sewer under the Great Highway are not known at this time. Construction of this connection may involve temporarily closing a portion or the full width of Fulton Street, and/or a portion of the Great Highway.

### 3.3 Tunneling Diagonally Across the Avenues

The tunnel would be constructed entirely from the portal, working up-grade towards Point B at 26th and Lake. Up-grade construction is convenient for the removal of water seeping into the tunnel. The portal location is also convenient for trucking of excavated materials. Tunneling from a shaft at Lake Street would be environmentally undesirable.

Several construction aspects combine to make this alignment unfavorable.

The contractor must prepare for two different types of tunneling operations, tunneling in soil under a very substantial head of water, and tunneling through rock. The segment through rock, near the middle of the tunnel, in all probability would be excavated by conventional drill-and-blast methods to a size that would allow the shield required for soil tunneling to be carried through the rock tunnel. During

rock tunneling, the complex excavation and propulsion equipment in the shield must be protected or removed. Two areas of difficult mixed-face conditions must be negotiated under the highest head of water.

Tunneling through the soil segments of this alignment would be difficult and expensive, irrespective of the rock and mixed-face conditions. Most of the soil tunneling would be through the Colma Formation sands, which are generally somewhat cemented. However, this formation contains layers or regions of uncemented sand. Under a high head of water, uncemented sands are unstable and will produce massive sand-water flows into the tunnel unless controlled. Such control may be provided in a number of ways, including compressed air tunneling, reduction or elimination of the water pressure by deep pumping, or by continuous face support using a slurry mole or a similar tunneling technique.

In this instance, a slurry mole or similar method would not be practical because the very complex machinery required for this type of tunneling would have to be removed under very trying circumstances, at the rock interface, and reinstalled on the other side of the rock segment. Such procedures are unprecedented, and considered technically infeasible at this time.

Compressed air tunneling is technically possible with a head of water even beyond 100 feet. However, the cost increases very rapidly with increasing air pressure to balance the water pressure, and compressed air tunneling is not considered practical for a head of water beyond 80 feet.

The solution to this problem considered in this study consists of dewatering by deep pumps, installed from the ground surface and drawing down the water table sufficiently for economical compressed-air tunneling. This requires the groundwater level within the Colma Formation to be drawn down along the alignment a maximum of at least 50 feet, which is considered difficult but feasible. The estimate presented in Section 7 is based on this construction method.

The combination of soil tunneling deep below the groundwater table, mixed face and rock tunneling make construction not only difficult but also encumbered by significant risks. Bid prices for a contract for this tunnel would not only reflect the high cost of dealing with difficult tunneling problems, but also significant contingencies associated with construction risks.

The Direct Route alignment would pass beneath a large number of private properties as it crosses diagonally from Point F to Point B. Tunneling through rock and soil at great depth can be performed with little or no surface effects, such as settlements or noise. However, tunneling of the first 2,000 feet, in dune

sands under shallow cover (less than 50 feet) is likely to cause disruptive settlements. Dewatering wells along the alignment would have to be placed, not only in street areas, but most probably, also within private properties.

If this alignment is considered further, rerouting from Point F North along the Great Highway, then East along Cabrillo or Balboa should be considered.

## 4. THE SOUTHERN ROUTE

### 4.1 Alignment and Geology

The Southern study alignment runs East from Point F along Fulton Street approximately 7,300 feet to 26th Avenue, Point E, from where it runs North for approximately 4,900 feet to Point B. With a length of 12,200 feet, it is the longest of the alignments.

There is some indication that the alignment along 26th Avenue could encounter a short stretch of rock or mixed-face conditions near Cabrillo Street. Results of additional explorations in this vicinity may require a re-evaluation of this alignment. Except for this possible rock occurrence, the tunnel would be entirely in dune sands and sands of the Colma Formation.

The first 2,400 feet of tunnel from Point F along Fulton Street would be in dune sands, with groundwater up to 40 feet above the crown, the remainder would be in the Colma Formation, with groundwater up to more than 90 feet above the crown in the vicinity of Point E. The maximum soil cover over the crown would be about 160 feet.

At 26th Avenue, a curve must be provided to allow the tunneling shield to negotiate the 90° turn.

An alignment along 27th Avenue was also considered. This alignment is likely to involve some rock tunneling between Cabrillo and Balboa Streets. Since the remainder of the tunnel would be entirely in soil, a segment of rock tunneling would be undesirable.

An alignment along 25th Avenue appears feasible. It would be more certain to avoid mixed-face tunneling but would entail a greater total length of tunneling.

### 4.2 Portal at Fulton Street and the Great Highway

Portal works and work area would be nearly identical to those required for the Direct Route, except that provisions for rock tunneling are not required.

### 4.3 Tunneling Along Fulton and 26th Avenue

The tunnel along Fulton Street could be placed directly under the street, but an alignment within the Golden Gate Park boundary is preferable. This alignment would be entirely under public lands and effects of settlements at the ground surface would be minimized.

Details of tunnel construction methodology can be worked out in a number of feasible ways. The method and sequence of construction described briefly in the following paragraphs is the basis for the cost estimate presented in Section 7.

The first 3,000 feet of tunneling would be in dune sands or Colma sands under a maximum head of about 40 feet of water. Tunneling in free air, using standard shield and excavating equipment, and preceded by deep-well dewatering is practical and economical for this stretch. The precise limit of free-air tunneling would be determined by the contractor, depending on actual conditions.

At this point, an air lock would be installed, and the remainder of the tunnel would be driven under compressed air. The required air pressure would be reduced by deep-well dewatering. The remainder of the tunnel would be in the Colma Formation, which is assumed to have some coherence in most areas, and the air pressure and pumping efforts would be adjusted continuously to suit the local conditions.

Approximately 9,200 feet of tunnel would be constructed in this fashion. For safety and convenience, the air lock would be moved ahead in the tunnel at least once or twice.

The tunnel would be lined with a segmented concrete lining, erected in the tail of the shield, designed to give a hydraulically acceptable interior finish. Alternatively, a metal lining could be erected, followed by an interior cast-in-place concrete lining.

Construction risks associated with this alignment are within ordinary tunnel construction standards.

An alternative to compressed air tunneling is the use of slurry mole or earth and water pressure balance technology. These techniques have been used extensively abroad, especially in Japan, but no American tunnel project has yet employed these methods. There is, therefore, no American cost experience, and a reliable cost estimate assuming such tunneling methods cannot be made. A preliminary assessment, however, shows that the cost would be comparable with that of compressed air tunneling. These technologies would not obviate the need for dewatering.

Should the Southern Alignment be considered for final design, the use of any one of these modern tunneling techniques should be considered. In the design documents, alternative tunneling methods of these types should be allowed.

### 4.4 Alternate Profile

A substantial cost associated with the Southern Route results from the need to drive the tunnel under compressed air. Much of this premium cost could be saved by raising the tunnel profile so as to minimize the head of water.

With a Lake Street Sewer elevation near 90 at Point B, the Lake Street-26th Avenue intersection, the Transport Tunnel could be raised more than 60 feet at this location. For the most ideal construction conditions, the tunnel would then be constructed with a minimum slope, along 26th Avenue and Fulton Street, to a point near 36th Avenue, at which point the profile would have to be steepened to a slope of 0.02 in order to stay below the ground surface and reach elevation 0 at Point F.

With this profile, the water head can be kept below 40 feet, and tunneling in free air, with dewatering along most of the length, is entirely feasible. Though the profile is not ideal for hydraulic reasons, its cost advantage, relative to the deeper profile along the same alignment, cannot be ignored. The comparative estimate given in Section 7 is based on the deeper alignment.

# 5. THE NORTHERN ROUTE

## 5.1 Alignment and Geology

This alignment runs North from Point F for about 2,000 feet in braced trench to a tunnel portal in rock about 500 feet North of Balboa Street. Tunneling would then be in rock for about 7,700 feet, followed by about 300 feet of mixed-face and soil tunnel, to Point B.

The trench tunnel segment would be in dune sands, with groundwater up to about 10 feet above invert elevation.

Geologic data available at this time indicate that approximately the first 2,000 feet of the rock tunnel would be driven through relatively competent sandstone, siltstone or shale of the Great Valley Formation.

Of the remaining 5,700 feet of rock tunnel, about 2,400 feet may be expected to be driven through relatively competent Franciscan graywacke with shale interbeds, or Franciscan formations composed of siltstone, shale and chert beds.

The remainder of the rock tunnel would be driven through Melange, a geologic material characterized as hard rock fragments embedded in a sheared matrix of shale or clay-like material. In one region, about one thousand feet long, the matrix dominates, with rock inclusions constituting only 20 percent of the mass and ranging from cobbles up to blocks larger than the tunnel. The remainder of the Melange, along a tunnel length of about 2,300 feet, consists principally of large or very large inclusions separated by small quantities of sheared shale matrix.

The last 300 feet of tunnel would be in the Colma Formation, with groundwater about 60 feet above the crown.

It must be recognized that the available geologic information is limited to only six borings within a corridor 200 feet wide, plus extrapolation and inference from other data. Construction feasibility and cost assessments are therefore subject to some uncertainty.

## 5.2 Trench Tunnel

The trench segment could be constructed under either La Playa Street or the Great Highway. At present, a location under the Great Highway is considered. Placing this segment under the vacant blocks between these streets is not desirable, because of plans to develop these properties.

In dune sands with a groundwater table only a few feet above the invert, this segment would be constructed using standard open cut and dewatering methods. Adjacent vacant lands, if still vacant at the time of construction, would allow removal of excavated soils to be done through haul ramps.

### 5.3 Portal at Great Highway, North of Balboa

In the vicinity of Point D, the proposed rock tunnel portal location, the Great Highway reduces in width from about 160 feet to the South to about 60 feet toward the North. A relatively large level area North of Balboa Street is vacant at present; this area would be an ideal construction site and work area. Where the Great Highway is wider than 60 feet, a portion of that highway may also be taken as a construction work area.

Space requirements for the portal work area have not been worked out in detail. The specific requirements would depend on the contractor's methods of operation. Different sets of requirements would ensue if the cut-and-cover and mined tunnels were to be built by different contractors; and the timing of the cut-and-cover work relative to the mining work would have a great effect on the work space required, and the degree of disruption imposed on the neighborhood.

Assuming that cut-and-cover work is performed independently and without interfering with mining, space requirements for mining would be assessed at approximately 40,000 square feet including access ramp, or close to an acre. It is possible to reduce this areal requirement but only at substantial cost.

Considerable difficulty would ensue if the tunnel portal were to be placed at the point where the Great Highway narrows down to about 60 feet. Since traffic on the highway must proceed unimpeded, there is not sufficient space to provide adequate portal access. Furthermore, the required work space, if entirely within the Great Highway, would extend so far that Balboa Street would be blocked. Access to the now vacant properties would also be impeded.

It is therefore recommended that the portal be placed at a location approximately 500 feet from Balboa Street, within the vacant land, and that an area of this land be taken for the duration of construction such that about an acre will be available to the contractor, including a portion of the highway, while allowing about a 60-foot highway width for unimpeded traffic.

Though it is desirable to allow contractor's use of the entire lot North of Balboa, it is possible to prohibit contractor's use of the southernmost 200 feet of the lot, allowing independent development of this area. After tunnel construction, a permanent easement under a small part of the northern portion of the lot would be required.

### 5.4 Tunneling in Rock to Lake Street

From the portal at Point D, rock tunneling would proceed up-grade toward Point B. Tunnel excavation would most likely be done by conventional drill-and-

blast techniques, and muck removal by muck trains on rails. The contractor should be allowed the option of driving either a circular or horseshoe cross section. In either case, it is assumed that the permanent lining would be cast-in-place concrete with a circular interior shape.

Temporary tunnel support may be provided by a selection of methods to suit local conditions, including shotcrete, shotcrete plus rock bolts, and steel sets with timber or shotcrete lagging.

The Great Valley Formation and the relatively competent portions of the Franciscan rocks are not expected to present unusual excavation or support problems. Zones of fractured and sheared rock may require rapid support and could locally slow down the rate of advance. The groundwater table is up to 300 feet above the crown; hence, water problems may be expected in pervious and fractured zones.

Tunneling through the Franciscan Melange will be difficult. Due to the great differences in hardness of the components of the Melange, excavation will require great care, and the excavated tunnel section will probably be quite irregular. The strength of the clay-like matrix is only modest, and rock falls, squeezing ground or other manifestations of unstable ground are likely to be experienced. Ground support will be difficult due to the potential instability of the rock and the likely irregular excavated surfaces. For these reasons, tunnel construction is assumed to proceed much more slowly in this Melange zone than elsewhere.

It may be assumed that the Melange consisting principally of clay matrix will be appreciably more difficult to tunnel through than the Melange comprised essentially of large blocks.

The short length of mixed-face and soil tunnel near Point B will most likely be constructed essentially by hand mining methods. A significant dewatering effort would be required to construct this tunnel by hand methods in free air. The cost of this reach has been isolated but included in the estimate shown in Section 7. An apparent solution to this local problem would be to locate the drop shaft 300 to 400 feet west of the location shown, where it would bottom out in bedrock. The soil tunnel segment would thus be avoided at the expense of adding an equivalent length to the Lake Street Sewer. This alternate is also discussed in Section 7. The most feasible location of the drop shaft can be determined only after additional explorations.

## 6. TUNNEL TO LOBOS CREEK

A relocation of the north-easterly end point of the Transport Sewer Tunnel to the vicinity of the Lobos Creek culvert under Lincoln Boulevard offers the following potential advantages:

- A reduction in length of the pressure line from Seacliff Pump No. 2 to the Transport Sewer.
- A reduction in future pumping costs because of a reduction in both length and lift height for the pressure line.
- Elimination of the drop shaft at Lake Street.
- Reduction of contract time, if this is important, by working two headings.
- A relatively convenient method of connecting the outfalls from 17th, 22nd and 24th Avenues to the Transport Sewer Tunnel, without requiring reconstructing of the Lake Street Sewer system.
- A lessening of the environmental impact by removing the construction disruption from Lake Street.

Either one of the three alternative routes could be extended to Lobos Creek.

The Direct Route alternative would be extended diagonally for approximately 1,000 feet, all by tunneling in soil, to the portal. The Southern Route most likely would be along 24th or 25th Avenue rather than 26th, to the portal, adding approximately 1,200 feet of tunneling in soil to the alignment. The Northern route would be relocated slightly and extended 1,100 feet. It would then include about 1,300 feet of tunneling in soil and mixed-face. In all three instances, the 2,600 feet of the Lake Street Sewer would be eliminated. The increase in cost for the added tunnel length is least for the Northern Route and the Northern Route is the basis used for estimating the cost of this alternative.

Space is available for a contractor's work area at Lobos Creek, within the Presidio. This permits driving the tunnel from two headings. The consequent reduction in project duration and, therefore, of extended overhead and escalation costs will more than offset the added cost of equipping a two-heading operation. If, for any reason, there is a prohibition on driving from a portal near Great Highway, the availability of this support site makes this project alternative more conomical than a similar restriction on the others.

Lobos Creek presents some design and construction problems. It crosses Lincoln Boulevard at invert elevation 27.5, close to the most convenient location of a portal for the soil tunneling. To pass over the Lobos Creek Culvert at this point, the Transport Tunnel invert would need to be at or above elevation 35.

However, because the 17th and 22nd Avenue outfalls about 500 feet due East of the proposed portal have invert elevations of about 30 and 38, it would be most desirable to maintain a Transport Tunnel invert at about elevation 28 to enable a convenient tie-in of the outfalls to the Transport Tunnel. A number of schemes can be developed to solve the interference problem between the tunnel and Lobos Creek; all involve reconstruction of parts of the 17th and 22nd Avenue outfalls, and of the Lobos Creek Culvert.

Considerable additional study is required to develop the most feasible solution in the region of Lobos Creek. The design for this region must enable connections to the 17th and 22nd Avenue outfalls and accommodate the flow from Seacliff Pump; it must provide for permanent, full-flow capacity for a reconstructed Lobos Creek Culvert, and for temporary handling of Lobos Creek flows during construction. Traffic must be maintained on Lincoln Boulevard and El Camino Del Mar, and the temporary and permanent impact of construction on Lobos Creek and on the neighborhood must be minimized while the tunnel portal could be placed either East or West of the culvert, the need to maintain flows in Lobos Creek and the desirability of minimizing tunnel length and, therefore, costs currently appears to favor the westerly location.

Since a detailed solution for this region has not been established, the estimate shown in Section 7 includes the cost of this work as an allowance. The allowance also includes a nominal sum for sewer hook-up work.

## 7. COMPARATIVE CONSTRUCTION COST ESTIMATES

### 7.1 General

Tunnel construction costs for the three basic alignments from the Fulton Street - Great Highway intersection to Lake Street, including the Lake Street sewer, have been estimated for comparative purposes. Costs have been based mostly on standard unit costs and are presented as 1978 costs without escalation.

A comparative cost is also shown for the Northern Route - Lobos Creek Alternate, including the cost of crossing Lobos Creek and an allowance for hook-ups to existing sewers.

Cost associated with contractor profits and overhead, mark-up on subcontractor costs, and insurance, are included as a percentage of the direct costs.

Cost of spoil haulage is based on a haulage distance less than three miles. Longer haulage distances will increase the cost of haulage.

The estimates do not include real estate or right-of-way costs, or specific environmental protection measures.

The estimates are based on construction of 15-foot tunnels from one portal at the western end, for the three basic routes while tunneling for the Lobos Creek alternate is assumed to be from both portals. Cost considerations for smaller size tunnels are presented in Section 8.

### 7.2 Estimated Cost, Lake Street Sewer and Drop Shaft

The 2,600 feet of sewer line in Lake Street, and the drop shaft at 26th Avenue, have not been estimated in detail. An estimate of $3,000,000 may be used for comparative purposes. This estimate is based on open cut construction and is common to all three basic study alignments.

### 7.3 Estimated Comparative Cost, Direct Route

Fifteen-foot tunnel mined from portal at Fulton and Great Highway to Lake and 26th, drop shaft,and sewer in Lake Street.

| Item | Length ft. | Cost in Thousands |
|---|---|---|
| Tunnel in soil, dewatered, free air | 3,100 | $ 5,000 |
| Tunnel in soil, dewatered, compressed air | 2,950 | 10,400 |
| Tunnel in mixed face, dewatered, compressed air | 350 | 3,500 |
| Tunnel in rock | 2,500 | 3,700 |

| Item | Length ft. | Cost in Thousands |
|---|---|---|
| Allowance * | - | 2,500 |
| Portal and work area, including compressed air plant | - | 1,000 |
| Lake Street sewer and shaft | 2,600 | 3,000 |
| Spoil Haulage | | 300 |
| Subtotal | | 29,400 |
| Contingency, 20% | | 5,900 |
| Subtotal | | 35,300 |
| Overhead, Profit, Insurance, etc. 25% | | 8,800 |
| TOTAL | 11,500 ft. | $44,100 |

## 7.4 Estimated Comparative Cost, Southern Route

Fifteen-foot tunnel mined from Great Highway, along Fulton to 26th, then North to Lake; drop shaft and sewer at Lake Street.

| Item | Length ft. | Cost in Thousands |
|---|---|---|
| Tunnel in soil, dewatered, free air | 3,000 | $ 4,700 |
| Tunnel in soil, dewatered, compressed air | 9,200 | 31,000 |
| Portal and work area, including compressed air plant | - | 1,000 |
| Lake Street sewer and shaft | 2,600 | 3,000 |
| Spoil Haulage | - | 400 |
| Subtotal | | 40,100 |
| Contingency, 20% | | 8,000 |
| Subtotal | | 48,100 |
| Overhead, Profit, Insurance, etc. 25% | | 12,000 |
| TOTAL | 14,800 ft. | $60,100 |

---

* Allowance for dismantling shield, moving it forward through rock tunnel, and reassembling; moving air lock forward; and other complications arising from tunneling in two different media along one length of tunnel.

## 7.5 Estimated Comparative Cost, Northern Route

Tunnel constructed in trench along the Great Highway from Fulton to Point D North of Balboa, then by mining through rock and a short length of soil to Lake and 26th, including Lake Street sewer and shaft. Basic cost below is for the scheme described above. The alternate following shows the effect of relocating the drop shaft 300 feet in a westerly direction to avoid soil tunneling.

Basic Cost:

| Item | Length ft. | Cost in Thousands |
|---|---|---|
| Great Highway trench tunnel | 2,000 | $ 1,700 |
| Rock tunnel, competent rock | 4,400 | 6,200 |
| Rock tunnel, Melange rock, Average quality | 2,300 | 4,000 |
| Rock tunnel, Melange rock, poor quality | 1,000 | 2,200 |
| Soil tunnel at Lake, dewatered | 200 | 600 |
| Mixed Face tunneling | 100 | 400 |
| Portal and work area | | 200 |
| Lake Street sewer and shaft | 2,600 | 3,000 |
| Spoil Haulage | | 400 |
| Subtotal | | 18,700 |
| Contingency 20% | | 3,700 |
| Subtotal | | 22,400 |
| Overhead, profit, insurance, etc 25% | | 5,600 |
| TOTAL | 12,600 ft. | $28,000 |

Alternate drop shaft location 300 feet West of Point B near Lake and 27th:

| Item | | Cost in Thousands |
|---|---|---|
| Basic Cost | | $18,700 |
| Deduct 300 ft. of soil and mixed face tunnel | | (1,000) |
| Add 300 ft. sewer in trench in Lake Street | | 400 |
| Subtotal | | 18,100 |
| Contingency, 20% | | 3,600 |
| Subtotal | | 21,700 |
| Overhead, profit, insurance, etc. 25% | | 5,400 |
| TOTAL | 12,600 ft. | $27,100 |

### 7.6 Estimated Comparative Cost, Northern Route - Lobos Creek Alternate

Tunnel constructed in trench along the Great Highway from Fulton to Point D North of Balboa, then by mining through rock towards Point C at Lobos Creek to the interface between soil and rock, approximately 7,800 feet from Point D. From the eastern portal at Lobos Creek, tunnel constructed by shield method to the rock interface, including reconstruction of Lobos Creek culvert.

| Item | Length ft. | Cost in Thousands |
|---|---|---|
| Great Highway trench tunnel | 2,000 | $ 1,700 |
| Rock tunnel, competent rock | 4,400 | 6,200 |
| Rock tunnel, Melange rock, average quality | 2,400 | 4,200 |
| Rock tunnel, Melange rock, poor quality | 1,000 | 2,200 |
| Soil tunneling | 1,200 | 2,500 |
| Mixed face tunneling | 100 | 400 |
| Portal and work areas | - | 400 |
| Allowance for Lobos Creek culvert, and miscellaneous sewer relocation | - | 400 |
| Spoil Haulage | | 400 |
| Subtotal | | 18,400 |
| Contingency, 20% | | 3,700 |
| Subtotal | | 22,100 |
| Overhead, profit, insurance, etc. 25% | | 5,500 |
| TOTAL | 11,100 ft. | $27,600 |

## 8. EFFECTS OF REDUCING TUNNEL DIAMETER

The estimates shown in Section 7 are based on a finished lining with 15-foot interior diameter;smaller diameters are now being considered by the City staff.

A change in diameter within a reasonable range, and certainly down to a 9 or 10-foot size, will not affect the relative merits and demerits of the alignments, or their relative cost position. The Northern Route and its Alternate will still be the most economical.

However, it cannot be expected that the estimated cost of a smaller diameter tunnel would be reduced in proportion to the cross section area, or even the diameter.

As an example, quantities of excavated materials and of concrete and other materials used for a 10-foot i.d. tunnel would be roughly 50 percent of those for a 15-foot tunnel. An added advantage to the smaller size tunnel is the fact that rock stability problems would be less severe, and full face tunneling can, most probably, be used also through the poorer quality rock.

However, because blasting will pull a shorter length of tunnel excavation per round in the smaller tunnel, and because space is more limited, the rate of advance is not likely to be increased (it could even be reduced), and hauling of rock through the tunnel to the portal will be less efficient. The required labor force would be of the order of three-quarters of that required for the 15-foot tunnel.

Overall, we estimate that the Northern Route - Lobos Creek Alternate if built with a 10-foot diameter instead of a 15-foot diameter, would cost 75 percent of the $27.6 Million shown in Section 7, or about $21 Million.

Within the estimating accuracy, tunnel sizes between 9 and 15 feet can be estimated by linear interpolation. Tunnels smaller than 9 feet in diameter would be increasingly less practical to build, and little economic benefit would be derived from considering tunnels of such sizes.

## 9. SCHEDULE CONSIDERATIONS

Project duration is controlled by the tunneling operations. The bulk of the cut-and-cover sewers along the Great Highway, and also in the Lobos Creek area, can be constructed simultaneously with, and in much less time than, the mined tunnel. However, an allowance of two months for completing the interface in the portal area is considered necessary.

Setting proper noise and vibration control levels will permit around-the-clock tunneling operations; accordingly, a schedule for the Northern Route - Lobos Creek Alternative has been developed on the basis of working from two portals on three eight-hour shifts, five days a week. Provision for adequate tunnel muck storage in the transfer area will eliminate need for truck transport on city streets during the night shift.

Twenty-six months will be required to mobilize, prepare the portal areas, and drive and line the tunnels. Adding two months for completing the interfaces results in a project duration of 28 months. Restrictions either of portal work area or of hours worked will increase both time and cost. If the tunnel must be driven from one portal only, 42 months would be required; the project costs would also increase markedly because of the extended overhead.

## 10. IDENTIFICATION OF ENVIRONMENTAL IMPACTS

Certain impacts of construction have been identified at this time, but further study is required to assess the magnitude and importance of these impacts. The impacts of construction of the Northern Route - Lobo, Creek Alternative include at least the following:

- Effects on Groundwater: Lowering of the groundwater will be limited in extent and is not expected to cause measurable settlements. Surface pumps and piping also will be minimal.
- Space Obstruction: Parking and traffic on the Great Highway will be affected north of Fulton Street. Fulton, Cabrillo and Balboa Streets may suffer temporary, partial closing. Traffic interruptions at Lincoln Boulevard will be minimal.
- Noise and Vibrations: Tunnel ventilation will generate significant high-pitched noise. Tunnel portal and work areas will generate ordinary construction noise. However, the muffling of ventilation and other stationary equipment is now commonplace when tunneling in urban areas and these noises can, therefore, be kept within acceptable limits. Truck traffic to and from the work areas will contribute to noise impact, but the daily tunnel traffic will be nominal because of relatively low haul requirements. Blasting noise and vibrations are not expected to be significant for rock tunneling because of the topography at the Great Highway portal and the absence of rock for more than 1,000 feet from the Lobos Creek portal.
- Visual Impact: The visual impact of construction will be the greatest at Lobos Creek, where a few private homes overlook the portal area.
- Easements: Provisions must be made to secure appropriate easements under a large number of private and public properties.
- Utilities: Though utilities have not been studied in detail, it appears that few, if any, existing utilities would be affected.
- Ecological Impact: A modest temporary ecological impact may be expected, particularly in the Lobos Creek area. Some plant growth may be disrupted. However, subsequent landscaping will eliminate permanent impact.
- Air Quality: Some dust and fumes, limited to the portal vicinities, may be expected.
- Traffic: Dump and delivery trucks, and workers' cars, will add to street parking and traffic.

## 11. CONCLUSIONS

The geotechnical explorations have sampled only a small fraction of the soils and rocks that will be encountered in tunneling along any one of the study alignments. Rock and groundwater contours are based on a very limited number of data points. In particular, the character of the bedrock mass along the Northern Route is not well-defined because of the much more variable nature of the rock as compared to the dune and Colma sands of the other route.

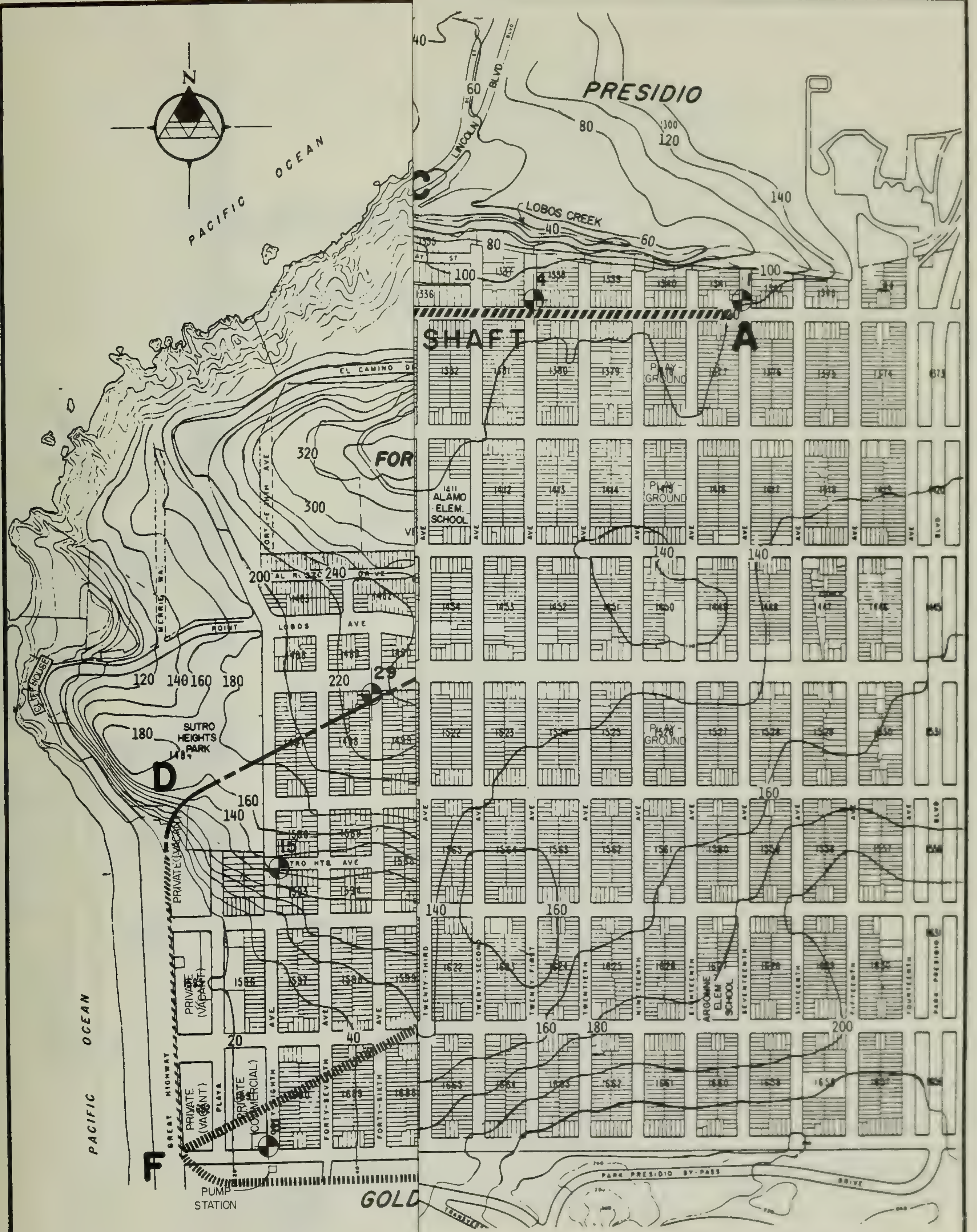
For these reasons, the estimates developed in this study must be used with care. Additional explorations carried out for purposes of refinement and further study of any potential alignment may disclose conditions that differ from the assumptions used in this study.

Environmental and institutional effects and constraints have not been considered fully in this study. For the final alignment selection, these items as well as the hydraulic characteristics of the several schemes described must be considered.

The conclusions reached in this study are, briefly, as follows:

- The Northern Route, essentially a rock tunnel, is the least expensive, by a substantial margin, and appears to offer the fewest engineering and construction problems.
- The Direct Route is the shortest route and is intermediate in costs. Its construction is complicated by the need to use both rock tunneling and compressed air soil tunneling techniques. It passes beneath numerous properties, some of which with the present alignment would be endangered by settlements (dune sand with shallow cover).
- The Southern Route is the longest and most expensive route. It would involve compressed air tunneling for most of its length.
- An alternate alignment of the north-eastern end of the Transport Sewer Tunnel to a portal near the Lobos Creek Culvert under Lincoln Boulevard, offers some attractive features:
  - Elimination of disruptive sewer and drop shaft work in Lake Street.
  - Shortening of the pressure line from Seacliff Pump No. 2.
  - Reduction in future Seacliff pumping costs.
  - Reduction of time required to construct the project.
- The Northern Route - Lobos Creek Alternative is estimated at $27,600,000 and can be built in 28 to 42 months, depending on work restrictions and conditions.

- The Northern Route - Lobos Creek Alternative appears to offer the least adverse construction impact, provided adequate work space is allowed at the portals.
- Though the Northern Route - Lake Street alignment and the Northern Route - Lobos Creek alignment appear essentially equal in estimated cost, lifetime economy, the lesser environmental impact, engineering practicality, and project duration all favor the Lobos Creek alignment.



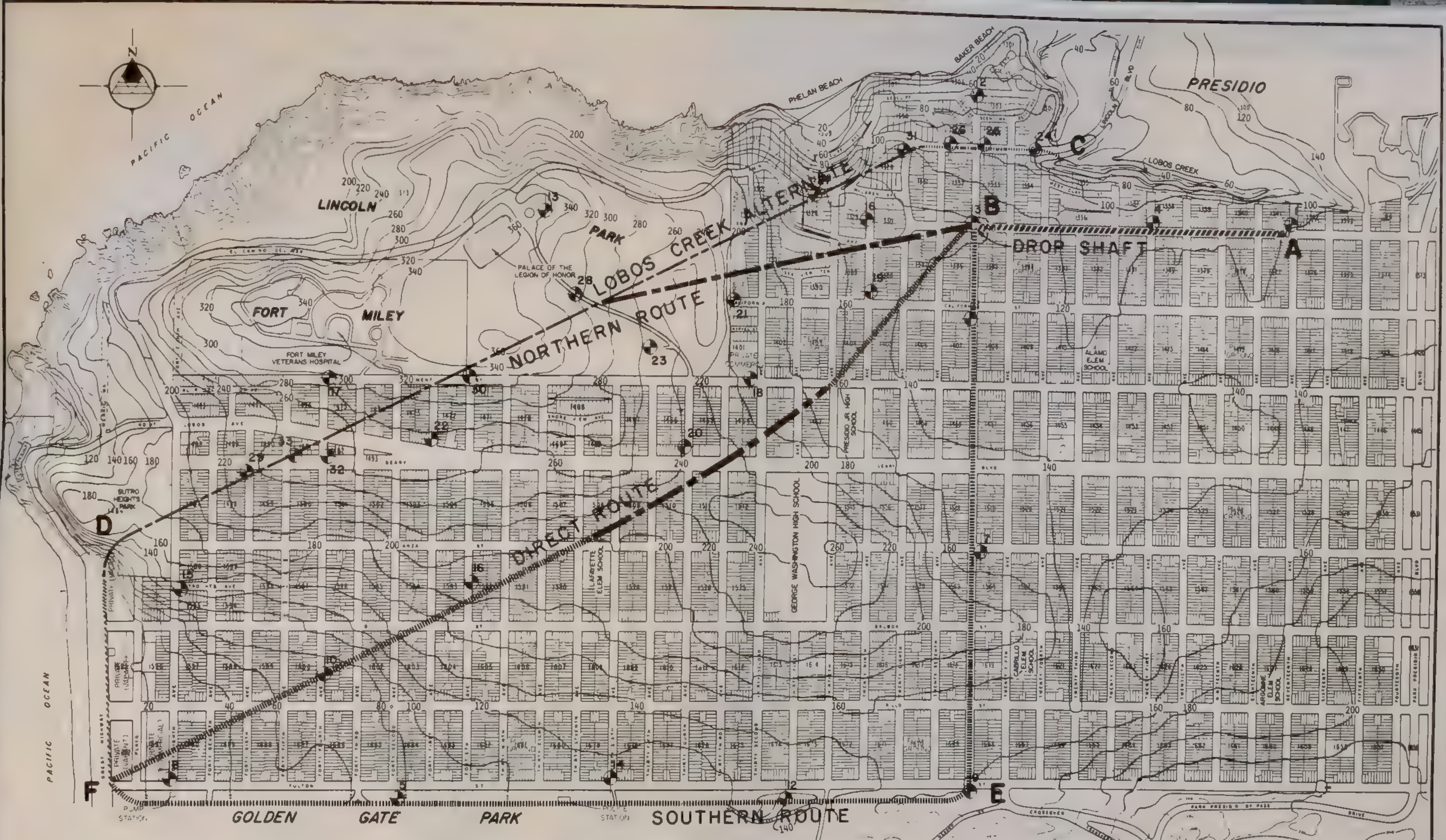
BASED ON PLAN BY
DAMES & MOORE
DATED 11/06/78

TRANSPORT SEWER TUNNEL
UDY ALIGNMENTS

FEET
500 0 500 1000

FEB. 1979 PBQ & D, Inc.

FIGURE 1



BASED ON PLAN BY
DAMES & MOORE
DATED 11/06/78

KEY PREFERRED ROUTE

| | |
|---|---|
| ▨ | CUT AND COVER TUNNEL |
| ▬ ▬ ▬ | MINED ROCK TUNNEL |
| ▨ | MINED SOIL TUNNEL |
| ⊕ | BORINGS DRILLED FOR THIS INVESTIGATION |

NOTES
1. CONTOURS ARE GROUND SURFACE ELEVATION BASED ON OFFICIAL CITY GRADE
2) DATUM USED IS CITY AND COUNTY OF SAN FRANCISCO (0 = MSL + 8.616 FEET)

## RICHMOND TRANSPORT SEWER TUNNEL STUDY ALIGNMENTS

FEET
500 0 500 1000

FEB. 1979 PBQ & D, Inc.

FIGURE 1

## PBQ & D, Inc.

San Francisco

A Subsidiary of: Parsons Brinckerhoff Quade & Douglas, Inc.

# CHMOND TRANSPORT SEWER

## MAIN COLLECTOR SEWERS

NO SCALE

(117) OFFICIAL STREET GRADE

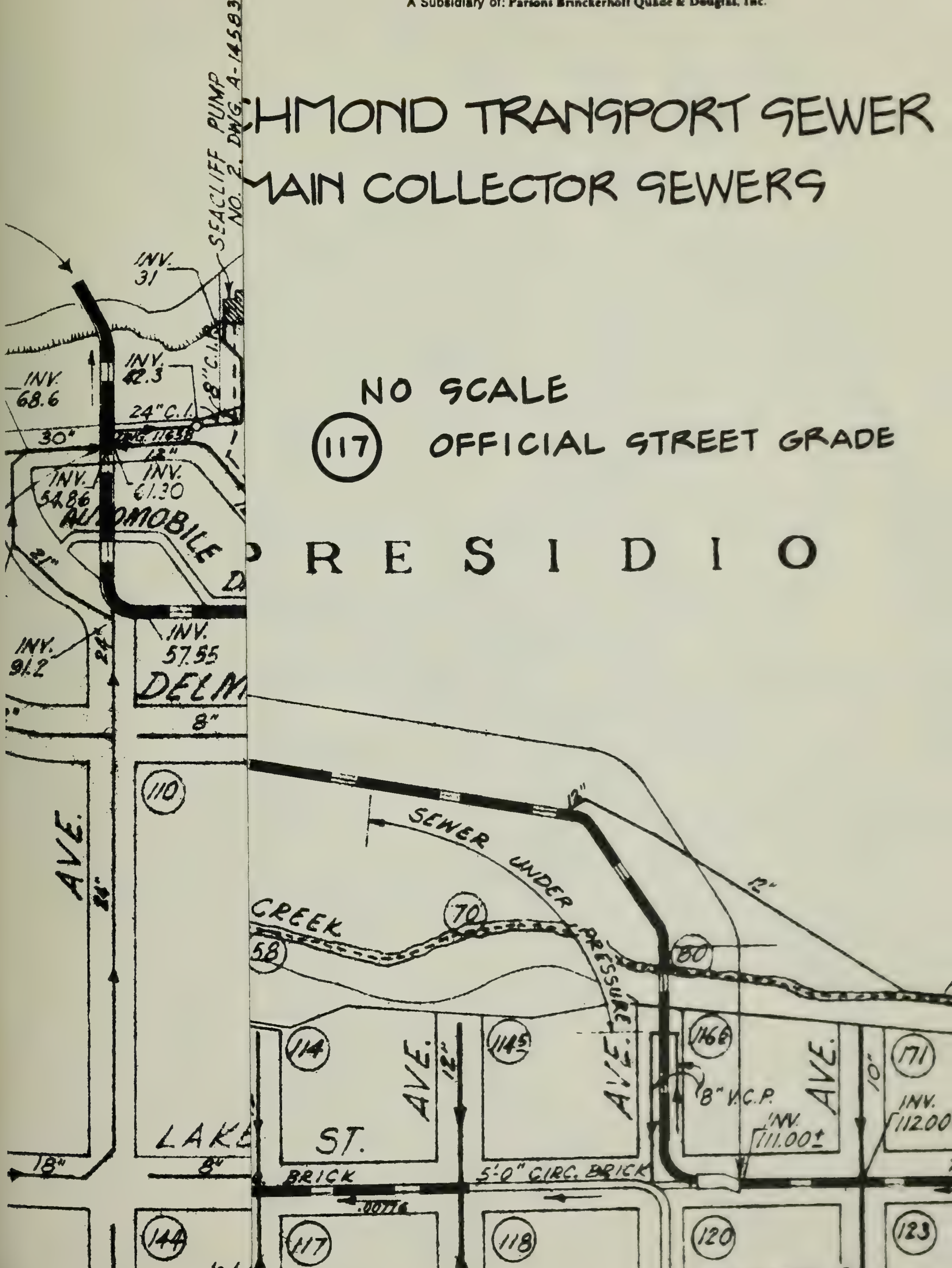
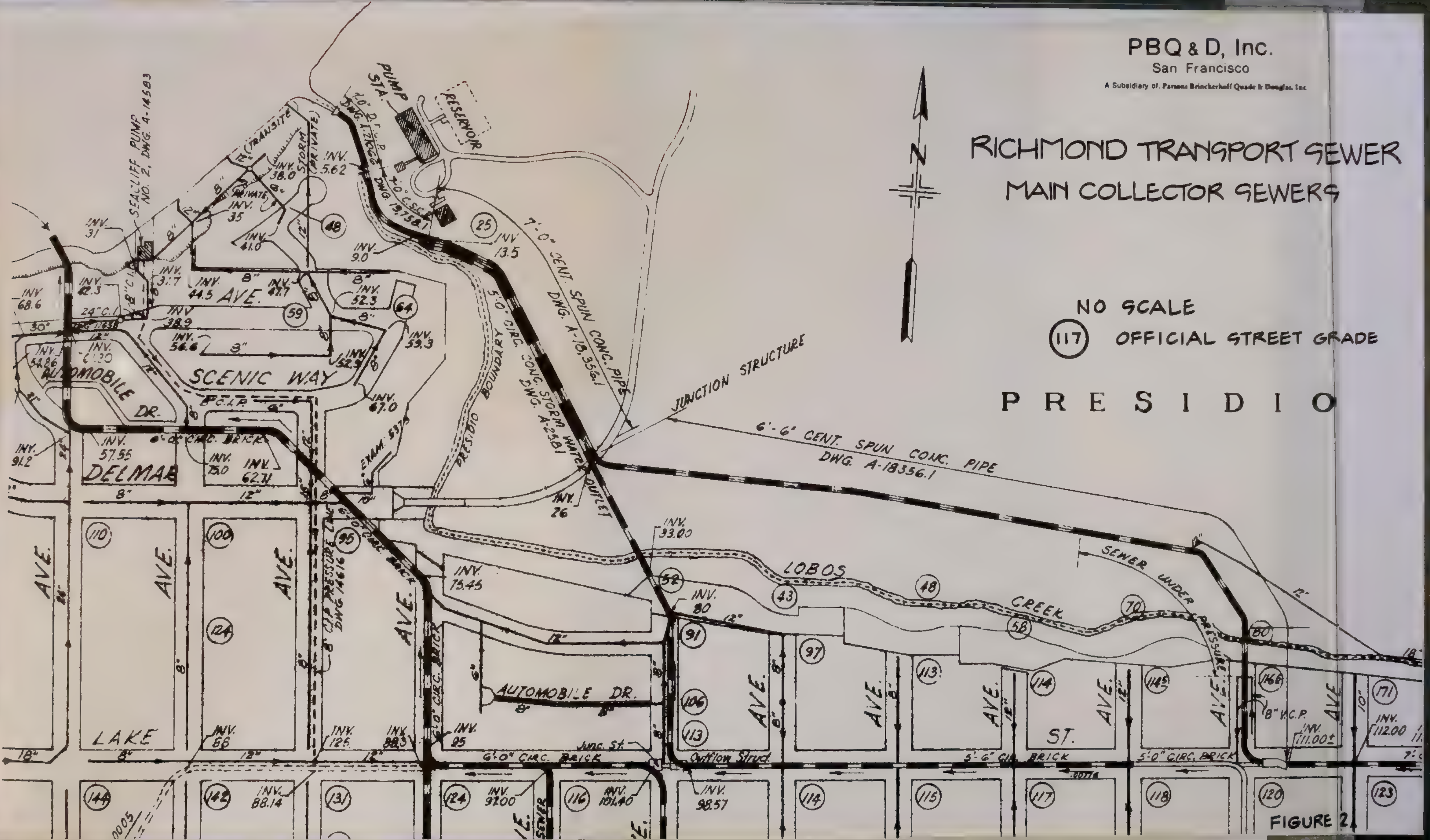


FIGURE 2



## PBQ & D, Inc.

San Francisco

A Subsidiary of Parsons Brinckerhoff Quade & Douglas, Inc

# RICHMOND TRANSPORT SEWER
## MAIN COLLECTOR SEWERS

NO SCALE

(117) OFFICIAL STREET GRADE

PRESIDIO

FIGURE 2

# APPENDIX D
# SEISMIC STUDIES

## D1.0 SEISMIC RISK EVALUATION

### D1.1 General Methodology

The seismic risk at the site was evaluated by summing the probable risk contributions from the individual faults surrounding the site. The steps in the analysis are as follows:

1) Establish the seismic setting. Review regional geologic and tectonic information to locate active faults.
2) Catalogue the seismic history. Prepare a list of earthquakes that have occurred, based on historic and instrumental records.
3) Calculate the seismic risk. Compute the probabilities of occurrence of ground surface accelerations for two design lives.

The three steps are explained in greater detail below.

Traditionally, seismic risk has been assessed subjectively from geologic and tectonic data and historical records. Generally the maximum event was estimated for each fault, then the maximum possible acceleration at the site was calculated using an attenuation relationship. Such studies are valuable for estimating the maximum loads that structures may be subjected to, but they do not indicate the probability of different acceleration levels occurring during the life of the structure.

For this study the seismic risk at the site was evaluated using a statistical method first presented by Cornell and Vanmarke (1969) and subsequently developed by Donovan of Dames & Moore. Details of the numerical procedure are given in publications by Donovan and Bornstein (1978). The region around the site was divided into discrete cells and the probability of different magnitude events occurring within each cell was computed, based on past seismic activity. The acceleration at the site from each postulated event was computed using an appropriate attenuation relationship. The contributions from all sources were then used to arrive at the probability of each acceleration level at the site. The results are expressed as the probability of each acceleration level being exceeded during the project

design life (50 or 100 years), as shown on Plates 10A and 10B in the main text. Site accelerations were calculated from two attenuation relationships; one generated from accelerations recorded on exposed bedrock and stiff soil sites, and the other from firm soil site accelerations.

## D1.2 Assumptions

A seismic risk analysis includes several assumptions regarding earthquakes. These assumptions are inherent in the subjective choice of earthquakes for seismic design but are often not clearly defined. The three principal assumptions are:

1. That the seismic history and tectonics are sufficiently well known to estimate the seismic activity of the region. The occurrence of each earthquake is assumed to be unaffected by previous or subsequent events, and recurrence intervals are assumed to be random. The latter assumption conflicts with the hypothesis that earthquakes are caused by the release of slowly accumulating crustal strains. However, the historical data is not extensive enough to justify a more sophisticated model.

2. That the rate of occurence of earthquakes can be expressed as a function of magnitude as follows;

   $$\log N = a - b_s M$$

   where N is the number of events of magnitude M or greater for the period being studied, and a and $b_s$ are constants dependent on the seismicity of the area.

3. That the decrease of acceleration amplitude with distance from the seismic energy source can be adequately expressed by an appropriate attenuation equation.

## D1.3 Source Model

The geographical region for the seismic risk model includes the major tectonic features and historic sources of seismicity surrounding the site. The region incorporated was large enough such that seismic risk contributions from the outside area may be considered negligible.

The earthquake source model for this study is shown on Plate D-1. A rectangular grid source model was chosen because: a) the grid easily reproduces irregular fault traces and b) the grid accurately models random areal activity. The computations of point source seismic risk contributions are more efficient than computations for other types of models, especially when the uncertainty of parameters such as the attenuation relationship are included in the analysis.

In addition to modeling the well-known primary faults in the San Francisco Bay Area, an upper bound or limiting magnitude was assigned to each source region. No rigorous method for evaluating this upper bound event has yet been devised. Therefore, the maximum event on each fault has been estimated by an empirical relationship between total fault length, fault rupture length, and magnitude.

Upper bound magnitudes were selected as follows. First, the total length of each fault shown on Plate D-1 was estimated from published geologic data. The rupture length for a given earthquake was then estimated. Observations by Albee and Smith (1967) indicate that fault rupture length typically ranges between one-fifth and one-half of the total fault length and that surface expression of the fault is usually one-third of the total fault length. The results of using empirical relationships between earthquake magnitude and fault length by Bonilla, Albee and Smith and Greensfelder are shown in Table D-1. The analysis is relatively insensitive to the choice of the upper bound magnitude as compared to the other parameters in the risk analysis; so the conservative assumption that the length of surface rupture is one-half of the total fault length has been adopted.

It has also been assumed that an event of up to magnitude 6.0 may occur anywhere within the source area. Major earthquakes have been recorded in California distant from known faults, and aftershocks of large earthquakes have been centered at considerable distances from the original epicenter.

## TABLE D-1

## LIMITING MAGNITUDES ON SIGNIFICANT FAULTS

| Fault | Total Length (kilometers) | Assumed Rupture Length (kilometers) | Maximum Credible Earthquake Greens-felder | Bonilla | Albee/ Smith |
|---|---|---|---|---|---|
| Hayward | 126 | 63 | 7.5* | 7.3 | 7.4 |
| Calaveras | 121 | 60 | 7.5* | 7.3 | 7.4 |
| Sargent Berrocal | 87 | 43 | 7.0 | 7.7* | 7.3 |
| San Andreas | 885 | 443 | 8.25* | 8.3 | 8.2 |
| Seal Cove-San Gregorio | 177 | 89 | 7.0 | 7.5* | 7.6 |
| Healdsburg | 42 | 21 | 6.75 | 6.6* | 6.5 |

---

*Value used as the upper bound in the seismic risk analysis.

### D1.4 Seismic Recurrence Rates

Two procedures have been presented in the literature for defining earthquake return rates as a function of magnitude. The more familiar is that derived by Gutenberg and Richter (1956) which expresses the magnitude of an event as a function of the logarithm of the number of events equal to or greater than that magnitude. Recurrence rates calculated from the historical data base are plotted on Plate D-2. The annual number of earthquakes exceeding a base magnitude and the magnitude-dependent recurrence rates must be estimated for the analysis. This information is also given on Plate D-2. Those events in the historical data base expressed by Modified Mercalli intensities were converted to Magnitudes using the empirical relationship (Richter (1958):

$$M = \frac{2}{3} I + 1.0 \qquad (1)$$

This equation converts integer Intensities to Magnitudes which are integer multiples of 1/3 as can readily be seen in the clustering of data points on Plate D-2. The following relationship between recurrence rate and Magnitude was obtained by a least squares curve fit to the data;

$$\text{Log } N = 4.81 - 0.56\ M \qquad (2)$$

where N is the number of events having a magnitude equal to or greater than M within a radius of 100 kilometers during the 166-year data period.

Seismic risk was computed in the analysis from the activity rate and magnitude distribution defined by Equation 2. 80 percent of the total activity was attributed to the known active faults with the remainder randomly distributed throughout the region. The activity was distributed along individual faults in proportion to their lengths.

## D1.5 Attenuation Relationship

### D1.5.1 Firm Soil Sites

Donovan (1973) developed the attenuation relationship for firm soils used in this study. Mean peak acceleration was computed from earthquake magnitude and hypocentral distance as follows;

$$y = 1080\ e^{0.5M}\ (R+25)^{-1.32} \qquad (3)$$

where $y$ = mean peak acceleration, in cm/sec$^2$

$M$ = magnitude

$R$ = hypocentral distance, in kilometers. For this study a focal depth of 15 kilometers was used.

This equation is plotted for several magnitudes on Plate D-3A.

### D1.5.2 Stiff Soil and Rock Sites

The attenuation relationship used for stiff soil and rock sites was developed by Donovan and Bornstein (1978) and is given below;

$$y = b_1\ e^{b_2 M}\ (R+25)^{-b_3} \qquad (4)$$

where y, M and R are as in equation (3)

and $b_1 = 2{,}154{,}000\ R^{-2.1}$

$b_2 = 0.046+0.193 \log R$

$b_3 = 2.515-0.212 \log R$

The rock and stiff soil attenuation relationship is shown on Plate D-3B.

Esteva (1970) and Donovan (1973) have shown that measured peak accelerations are lognormally distributed about the mean. The randomness in the attenuation relationship has been included in the seismic risk analysis (Donovan and Bornstein, 1978). The results obtained by including this uncertainty provide the best estimate of the mean recurrence rate for the mean peak acceleration. For this study, a fixed uncertainty (standard deviation) of 0.5 was used to represent the scatter in the attenuation data for firm soil sites. The standard deviation decreases from 0.48 to 0.3 with increasing acceleration in the stiff soil and rock site attenuation relationship used in the analysis.

## D2.0 SEISMIC SITE RESPONSE ANALYSIS

### D2.1 General

The seismic response of soil and rock at the site during a major earthquake was investigated in three stages: 1) evaluation of soil and rock properties, ground water elevation and penetration resistance information from boring logs, 2) static and dynamic testing of soil samples in the laboratory and 3) seismic response studies to estimate the peak ground motion and liquefaction potential during a major earthquake.

The soil and rock profiles used for the seismic site response analysis were based on the results of the subsurface investigations described in the main report and in Appendix A. These data included a limited amount of information obtained from reports by others, notably near the Great Highway at the former Playland-At-The-Beach area (Lee and Praszker, 1972). Representative static soil properties such as moisture and density, grain-size distribution, shear strength, and permeability were selected from the results of the testing program conducted for the subsurface investigation.

### D2.2 Ground Response Analysis

The soil and rock topography vary widely across the site and as a consequence the characteristics of earthquake induced ground motion may also vary widely. Four types of soil and rock profiles have been identified along the three alternate routes. They are classified as follows, in terms of the type and depth of soils and/or rock covering the tunnel;

a) Massive rock profile. A tunnel following the northern route would be covered by up to 300 feet of sedimentary and metamorphic rock. Rock conditions range from massive and very hard to fractured and highly weathered.

b) Rock ridge under soil. If the tunnel followed the direct route, it would penetrate a rock saddle midway between its endpoints. The rock section would be about 2500 feet long, with about 200 feet of rock under 50 feet of soil at the point of deepest cover.

c) Soil profile. Both ends of the northern and direct routes, and all of the southern route would be excavated in soil with a depth of cover ranging from virtually zero to as much as 200 feet.

d) Rock/soil transition. A tunnel following either the northern or direct routes would begin in soil, pass through rock, then enter soil again. The soil cover along the northern route would be fairly shallow at the rock-soil interface, while on the direct route, the tunnel would leave the rock about two hundred feet below the surface.

### D2.2.1 Massive Rock Profile Response

Seismic response within rock masses has not been extensively studied in the past because structures in rock have historically suffered little earthquake-induced damage. It is generally accepted that peak accelerations decrease slightly with depth within the rock mass. It is our opinion however, that the difference in response would be too slight to have much engineering significance in this case.

Rock quality and the orientation of discontinuities can affect local rock mass response. Relative motion and permanent deformation in the rock during earthquake shaking generally take place along existing joints, shear planes and faults.

### D2.2.2 Rock Ridge Response

The seismic response of the rock within an isolated rock ridge, as in the direct route, would probably be somewhat greater than the response of massive rock.

Bedrock surface geometry can amplify seismic motions. Recorded accelerations on a rock promontory (Pacoima Dam site) during the 1971 San Fernando earthquake were much higher than those recorded in the valley below. Most of the structures damaged by the 1957 San Francisco earthquake were on a bluff overlooking the ocean (Oakeshott, 1959). It is quite probable that rock motion displacements increase in rock ridges and promontories.

### D2.2.3 Soil Response

The response of a soil profile to strong earthquake motion may differ significantly from the induced motion in rock. Displacements and hence strains are usually greater in soil than in rock. Soil response to both body waves and surface waves were considered and a discussion of each is given below.

#### D2.2.3.1 Soil Response to Body Waves

The response of representative soil profiles to vertically propagating shear waves was evaluated by the method of Schnabel, et al., (1972). Based on the representative profiles shown on Plate D-13, 200-foot, 150-foot and 50-foot soil columns were analyzed using the S80E component of the Golden Gate Park record of the 1957 San Francisco earthquake (maximum acceleration =0.13g) and by the same record amplified by a factor of three (maximum acceleration =0.39g) as bedrock motions. The original accelerogram was recorded on a rock outcrop. The record represents rock surface response to moderate shaking on a nearby section of the San Andreas fault. The results of the analysis are summarized on Plate 11 of the main text.

The characteristics of the one-dimensional dynamic response analysis were examined in detail to assure proper interpretation of the results. The computed motion represents the seismic response of a horizontally-layered soil profile of semi-infinite lateral extent. Thus, the real soil profile shown on Plate 13 differs from the idealized soil column model. The soil layers are not horizontal, and the soil motion in the plane of the section is restrained on one side by the emerging rock mass. The real rock surface is not horizontal and the maximum rock surface motion is also unlikely to be horizontal. Significant energy may propagate towards the surface at an angle with the vertical, rather than vertically as assumed in the model.

The response of a soil layer over a sloping rock surface has been studied in detail by Dezfulian and Seed (1970). The computed response of a series of soil columns representing the sloping bedrock profile was compared with a more rigorous two-dimensional finite element solution.

Seed et al., (1972) also analysed the response of an alluvium-filled valley over a sloping rock surface in Caracas, Venezuela. The results of this analysis were in good agreement with the observed building damage after the 1967 Caracas earthquake.

These studies have indicated that the shallow soil surface acceleration computed by the soil column analysis is usually slightly higher than the surface acceleration computed by the finite element analysis.

Both of the studies cited above concluded that ground motions in soil over a sloping bedrock surface are amplified in the shallow soil region just in front of the emerging bedrock surface. The one-dimensional soil column analyses performed for this investigation also indicate that the soil response will be greatest near the emerging rock slope. Deep soil acceleration response, and horizontal strains throughout the profile are expected to be about the same for the two methods of analysis. The results of the soil column analyses agree well with observations of high ground disturbance at the edge of soil deposits during the 1906 San Francisco earthquake (Lawson, 1908).

The pattern of acceleration amplification in the soil columns also varies with the peak base acceleration amplitude. The deep soil column amplifies moderate base motion (0.13g) slightly, but it deamplifies the stronger motion (0.39g) significantly. The shallow profile amplifies moderate base motion more than strong base motion.

The direction of fault movement influences the directional distribution of soil response in a horizontal plane. The accelerograms recorded during the 1957 San Francisco earthquake (Oakeshott, 1959) reflect this variation. Strike-slip motion on the San Andreas fault produces shear waves with higher amplitude in a direction parallel to the fault trace.

### D2.2.3.2 Soil Response to Surface Waves

Soil response to Love and Rayleigh surface waves was also considered. Love waves create ground motion in a horizontal plane transverse to the direction of propagation while Rayleigh waves result in ground motion in a counter-clockwise ellipse in a vertical plane parallel to the direction of propagation. The fault movement direction and fault orientation with respect to the site determine the relative amplitude of surface waves in a given direction. These waves are produced when body waves intersect surface soil and rock layers at a low angle and propagate along the surfaces of these layers. Their amplitude usually become significant at epicentral distances greater than the depth of the major energy release. Although all earthquakes produce surface waves over a broad range of frequencies, the bulk of the wave energy is transmitted at relatively low frequencies, usually less than about 2Hz.

Surface wave amplitudes increase significantly as the waves propagate from near-surface bedrock into a deep soil with a lower natural frequency. Drake and Mal (1972) have studied the amplification of surface waves as they propagate from a rock outcrop into a soil layer of gradually increasing thickness. Surface wave acceleration amplitudes are usually lower than body wave acceleration amplitudes, but surface wave displacements and strains are usually greater than those produced by body waves. Soil displacements will control the tunnel response, thus surface wave displacement amplitude criteria are important to this project.

### D2.3 Slope Stability

Based upon an evaluation of the topography and subsurface conditions throughout the study area, it is our opinion that the only location where seismically induced slope failures are likely to influence the proposed construction is adjacent to Lobos Creek. At this location, shallow raveling of the steep slopes south and west of the creek and of the Lincoln Boulevard embankment over the creek might be expected during strong earthquake shaking. Even under these conditions, it is our opinion that the tunnel would probably not be endangered by the slope instability.

If, however, strong earthquake shaking resulted in soil liquefaction in the streambed deposits near or under the toe of these slopes, the probability of deeper slides occurring increases. These deeper slides may lead to tunnel damage. Even the very flat slopes near the Great Highway may be subject to instability if extensive soil liquefaction were to occur. The liquefaction potential is discussed in section 3.7 of the main report and the method of analysis is described below.

### D2.4 Liquefaction Potential Analysis

Three sections of the study area were identified as being most susceptible to liquefaction. These areas are 1) the region near the Great Highway from Fulton Street to Sutro Heights Park, 2) the northern edge of Golden Gate Park and Fulton Street from the Great Highway to 26th Avenue, and 3) the Lobos Creek area, particularly the streambed itself. There was insufficient field data to perform an analysis for the Lobos Creek area, so our evaluation of this area is based upon a literature review of the performance of stream channel deposits during strong earthquakes (Lawson, 1908).

For the Fulton Street and Great Highway area, the liquefaction potential in the dune sand above and around the tunnel was investigated by two methods: dynamic laboratory tests on representative samples, and evaluation of field blow count values. Blow count data and test samples for the analyses were obtained from the Great Highway area, El Camino del Mar, and the north side of Golden Gate Park.

All of the liquefaction analyses were directed toward evaluating the performance of dune sand. The liquefaction potential of Colma sand was not investigated because it is considered to be more resistant to liquefaction than dune sand. The results of the liquefaction analyses are discussed in section 3.7 of the main report and are summarized below.

It is concluded that widespread liquefaction of the soils around the sewer is unlikely. However the alluvium at the bottom of Lobos Creek and localized zones near the Great Highway could liquefy during a major earthquake. Many cases of stream-bed liquefaction during the 1906 earthquake are documented in the Lawson report. It is our opinion, however, that the tunnel could be designed to safely span small localized areas of liquefaction.

Slope instability of the Lincoln Boulevard embankment due to liquefaction in Lobos Creek could also affect the sewer unless adequate protective measures are incorporated during construction.

### D2.4.1 Method of Analysis Based on Blow Count Data

The soil blow count data from the borings was evaluated according to the simplified method presented by Seed (1976). Two analyses were carried out: one for conditions near the Great Highway, and one for conditions along Fulton Street on the north side of Golden Gate Park.

All standard penetration values (N-values) were normalized to an effective overburden pressure of 1 ton per square foot. Blow counts from the Dames and Moore U-Type samples were converted to equivalent standard penetration test (SPT) values by a relationship derived from borings in which both SPT and U-Type samples had been taken. Normalized penetration resistance values from the same depths in different borings were then averaged and the standard deviation computed. These data are plotted on Plates 12A and 12B for each of the two study areas.

The ratio of cyclic shear stress to effective overburden stress required to cause liquefaction at each depth was then evaluated from the empirical relationship presented by Seed (1976). For the Great Highway area, this evaluation was based on a peak ground surface acceleration of 0.48g as calculated in the soil response analysis for shallow soil conditions. For the Fulton Street/north edge of Golden Gate Park area, the evaluation was based on a peak ground surface acceleration of 0.26g as computed in the soil response analysis for deep soil conditions.

The results are shown on Plates 12A and 12B as the minimum normalized blow count, $\overline{N}_1$, required to resist liquefaction. In both instances the computed minimum $\overline{N}_1$ line is significantly less than the mean (normalized) blow count measured in the field, indicating that widespread liquefaction is unlikely. However, the spread of the data relative to the location of the $\overline{N}_1$ line suggests that liquefaction is possible in localized zones.

### D2.4.2 Laboratory Testing for the Liquefaction Study

A testing program was carried out to investigate the liquefaction potential of the upper dune sands. The program included stress-controlled cyclic triaxial tests, undrained compression tests to measure residual strength after liquefaction and relative density tests to determine the possible effects of sample disturbance. The grain size distribution of the samples was also measured.

Stress-controlled cyclic triaxial tests were performed on samples from different parts of the site. Four samples were selected from a depth of approximately 20 feet and reconsolidated to a uniform confining pressure simulating the overburden pressure. A fixed-amplitude sinusoidal vertical load was then applied to the top of each sample and the number of load cycles to liquefaction measured. One sample was tested at a load amplitude of 15% of the overburden pressure, two at 25% and one at 30%. The number of cycles required to produce 10% axial strain for the four samples is shown on Plate D-4. The results of each of the four tests are shown on Plates D-5A through D-9B.

The results shown for sample 5-2B reflect greater disturbance during field sampling and sample preparation than for the other tests. The relatively large number of cycles shown for sample 8-9 at 10% strain was caused by a reduction in load amplitude after about 10 cycles.

Although all test data points do not fall on a smooth curve, the test results are consistent with the sample quality and test loading conditions. The slope of the curve through the data compares well with the typical curves from tests on other clean fine sands.

The cyclic triaxial test specimens were subjected to monotonically increasing axial strain under undrained conditions immediately after the dynamic tests. The test results are shown on Plate D-11 in terms of the residual shear strength of the soil after liquefaction.

The similarity of grain size distributions of the four test samples is illustrated on Plate D-12.

## D3.0 GROUND/STRUCTURE DYNAMIC INTERACTION

This section discusses the dynamic interaction of the tunnel structure and the surrounding ground. Critical portions of the tunnel for seismic design are identified.

### D3.1 Rock Tunnel Response

The causes of damage to lined tunnels during earthquakes have been studied and documented by Dowding (1978). He investigated the dynamic interaction between the tunnel and its rock environment, and prepared recommendations for safe tunnel design and construction.

Dowding found that earthquake-induced damage to tunnels in intact massive rock is usually slight, even during major earthquakes. An important factor contributing to the low tunnel damage is that the lowest natural frequency of Rayleigh waves that may propagate around the inside of the tunnel liner is higher than the earthquake frequencies carrying significant energy. A second factor is that, whereas ground motion displacements, not accelerations, control the tunnel response, displacements are normally much lower in bedrock than in soil.

The only documented earthquake-induced tunnel failures have occurred at active fault crossings (Dowding, 1978). Fortunately, the proposed tunnel does not intersect any known active faults.

Strong ground motion may damage tunnel liners if firm contact with the rock wall is not provided. Large voids between the tunnel liner and rock wall should be filled with grout. Highly weathered or shattered rock around the tunnel should be cleaned carefully to assure the best possible contact with the liner.

### D3.2 Soil Tunnel Response

Seismically induced loading occurs from the relative motion of different sections of the tunnel. Displacement compatibility generally exists between the tunnel and the surrounding media.

These relative motions between adjacent tunnel sections generate axial, shear and bending loads in the tunnel. Field measurements of actual seismic tunnel response, model tests and theoretical analyses have demonstrated that axial loads and deflections, rather than shear or bending loads and deflections, will usually control design (Goto et al., 1973, Okamoto et al., 1973).

Theoretical expressions for dynamic axial and bending strains in a straight tunnel have been developed by Sakurai and Takahashi (1969).

Sakurai, et al. (1973) also derived an expression for the vertical variation of first-mode maximum shear strains induced in soil by strong ground motion. The expression is a function of the difference in velocity between two seismic waves traveling in opposite directions. Soil strains may also be obtained from one-dimensional soil response analyses.

### D3.3 Soil/Rock Transition

The seismic response of a rock mass and of a shallow the soil profile may differ significantly. A zone of relatively large strain and acceleration gradients may therefore be expected near the interface between the two materials.

These gradients may cause high relative displacements close to the interface. Body and surface wave soil displacements may be significantly higher than displacements in the adjacent rock. Tunnel sections at the rock portals will be points of relative structural fixity. Axial and transverse relative displacements between the tunnel and the surrounding soil may generate significant axial, shear and bending forces. An expression for the concentrated moment near the interface between two materials with different rigidities has been developed by Goto, et al. (1973).

In practice the strain induced in the tunnel close to the soil/rock interface during strong ground motions cannot be reduced by strengthening the structural design. Stresses can generally be reduced, however, by design measures to increase the ductility of the structure at these transition zones.

### D3.4 Soil Liquefaction Zones

Extensive liquefaction of the soil under or around the sewer may generate significant tunnel loads and displacements. The potential for and possible locations of soil liquefaction have been discussed in section 3.7 of the main text and section D2.4 of this Appendix. The magnitude of loading is largely a function of: 1) the extent of the liquefied zones, 2) whether the sewer developed positive or negative bouyancy during soil liquefaction and 3) whether any lateral movement of the soil mass occurred due to simultaneous

slope instability. It is our opinion that serious consideration of the above factors would only be necessary if the sewer alignment crossed Lobos Creek. In this case a short section of the sewer may require special design measures to resist soil instability. Liquefaction of localized pockets of loose soil is also considered to be possible near the Great Highway, but it is our opinion that the affected zones would be small enough for the sewer structure to span them without extraordinary design measures.

### D3.5 Structure Transition Zones

Significant bending moments can be generated during strong shaking at sharp bends in the tunnel. Tunnel bends should be gradual if possible and provided with extra ductility. Similary junction structures and abrupt changes in section geometry may also be critical areas for seismic resistant design.

The following Plates are attached to and complete Appendix D:

| | |
|---|---|
| Plate D-1 | Seismic Source Model Used for Risk Analysis |
| Plate D-2 | Recurrence Curve |
| Plate D-3A | Attenuation Relationship for Firm Soil Sites |
| Plate D-3B | Attenuation Relationship for Rock/Very Stiff Soil Sites |
| Plate D-4 | Summary of Stress-Controlled Liquefaction Tests on Dune Sand |
| Plates D-5A through D-9B | Results of Cyclic Triaxial Test |
| Plate D-10 | Methods of Performing Cyclic Triaxial Tests |
| Plate D-11 | Residual Strength of Stress-Controlled Cyclic Triaxial Test Samples |
| Plate D-12 | Grain Size Distributions |
| Plate D-13 | Representative Profile for Soil Column Response Analysis |

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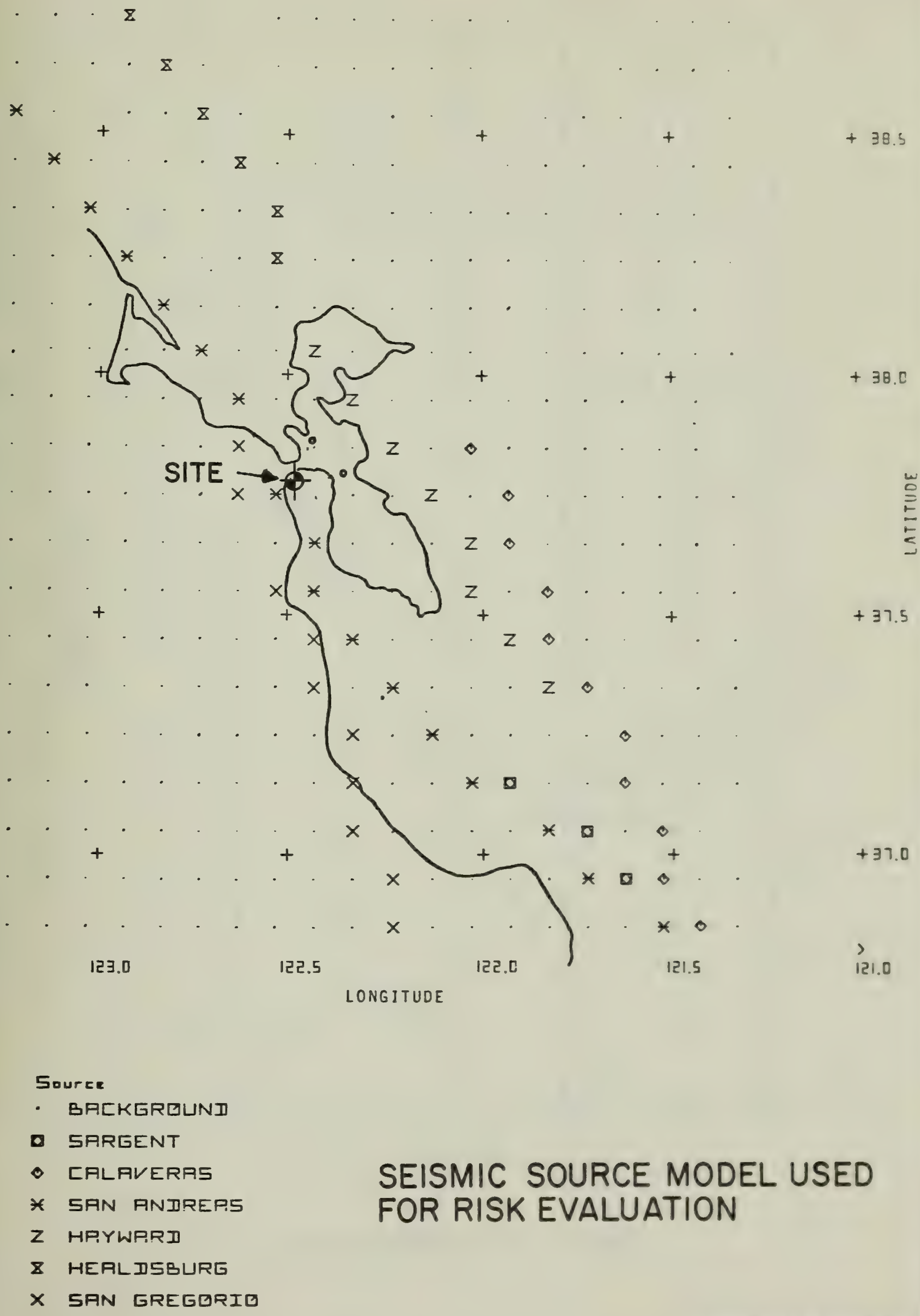
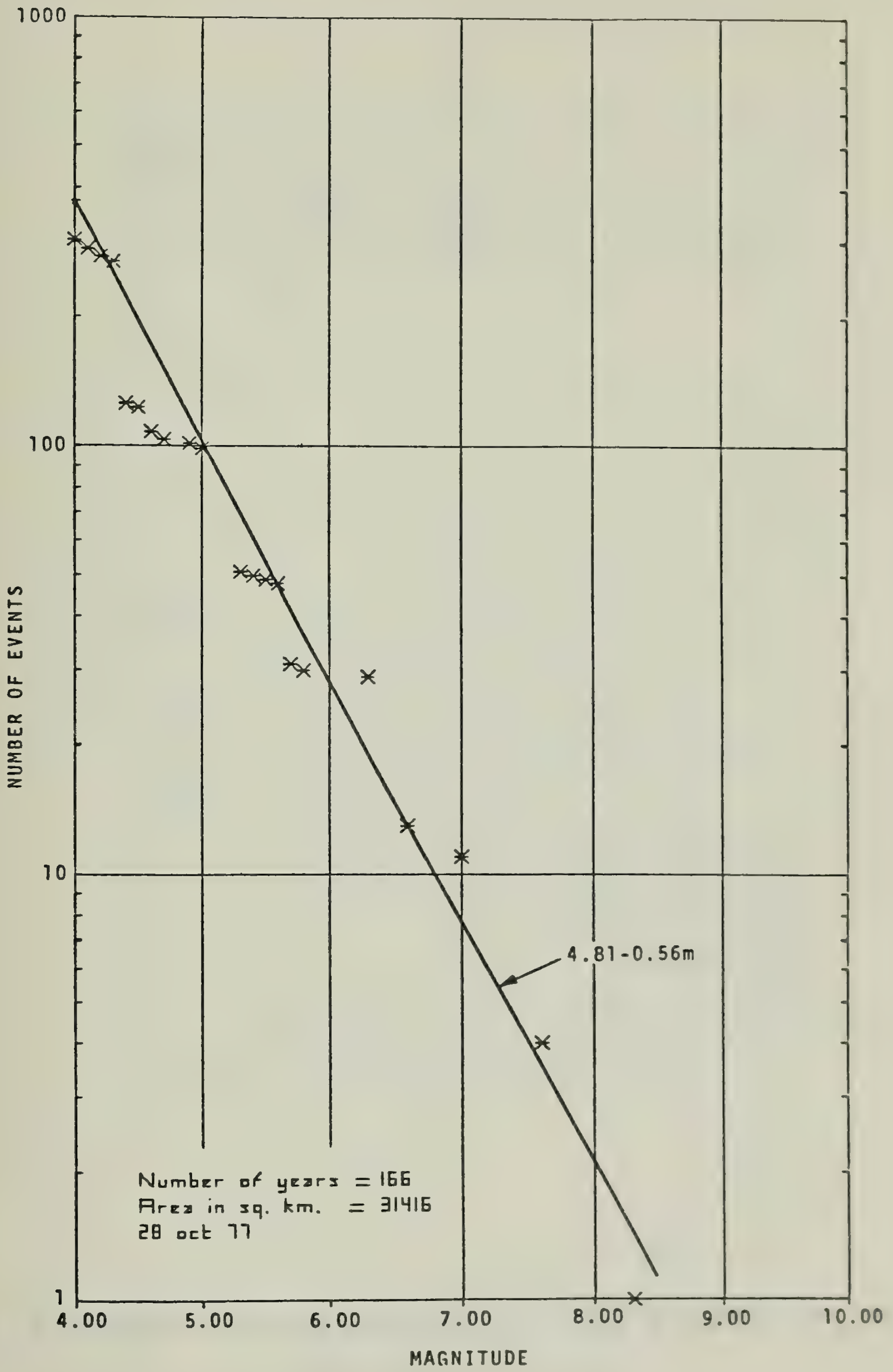


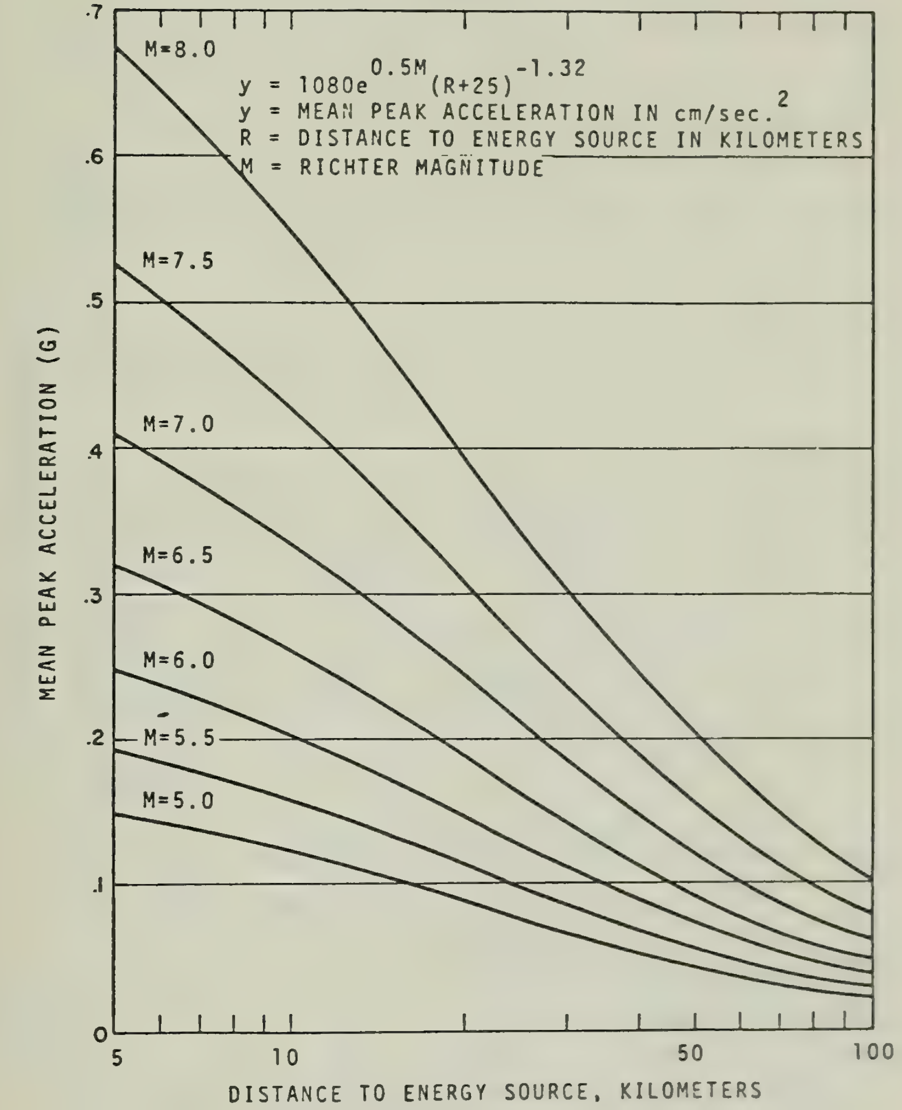
SEISMIC SOURCE MODEL USED FOR RISK EVALUATION

PLATE D-1



RECURRENCE CURVE

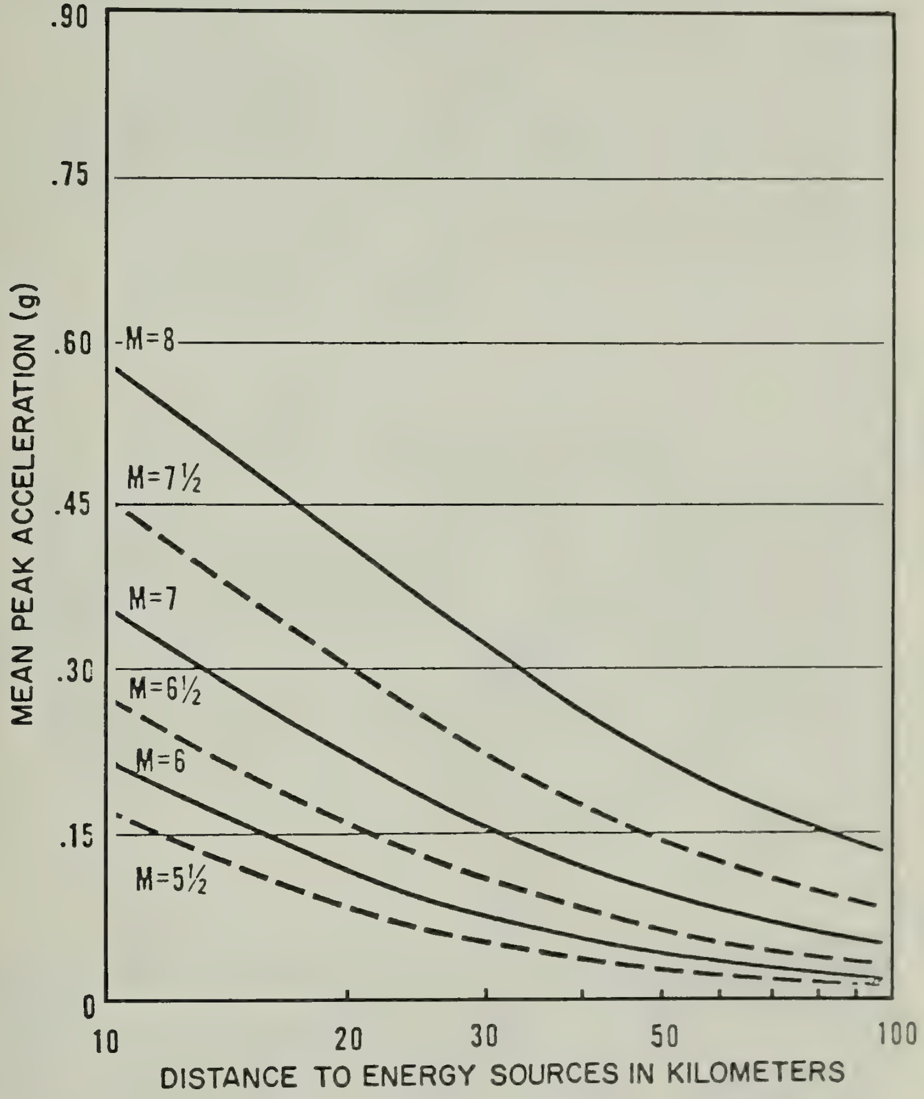
DAMES & MOORE



# ATTENUATION RELATIONSHIP FOR FIRM SOIL SITES

(AFTER DONOVAN, 1973)

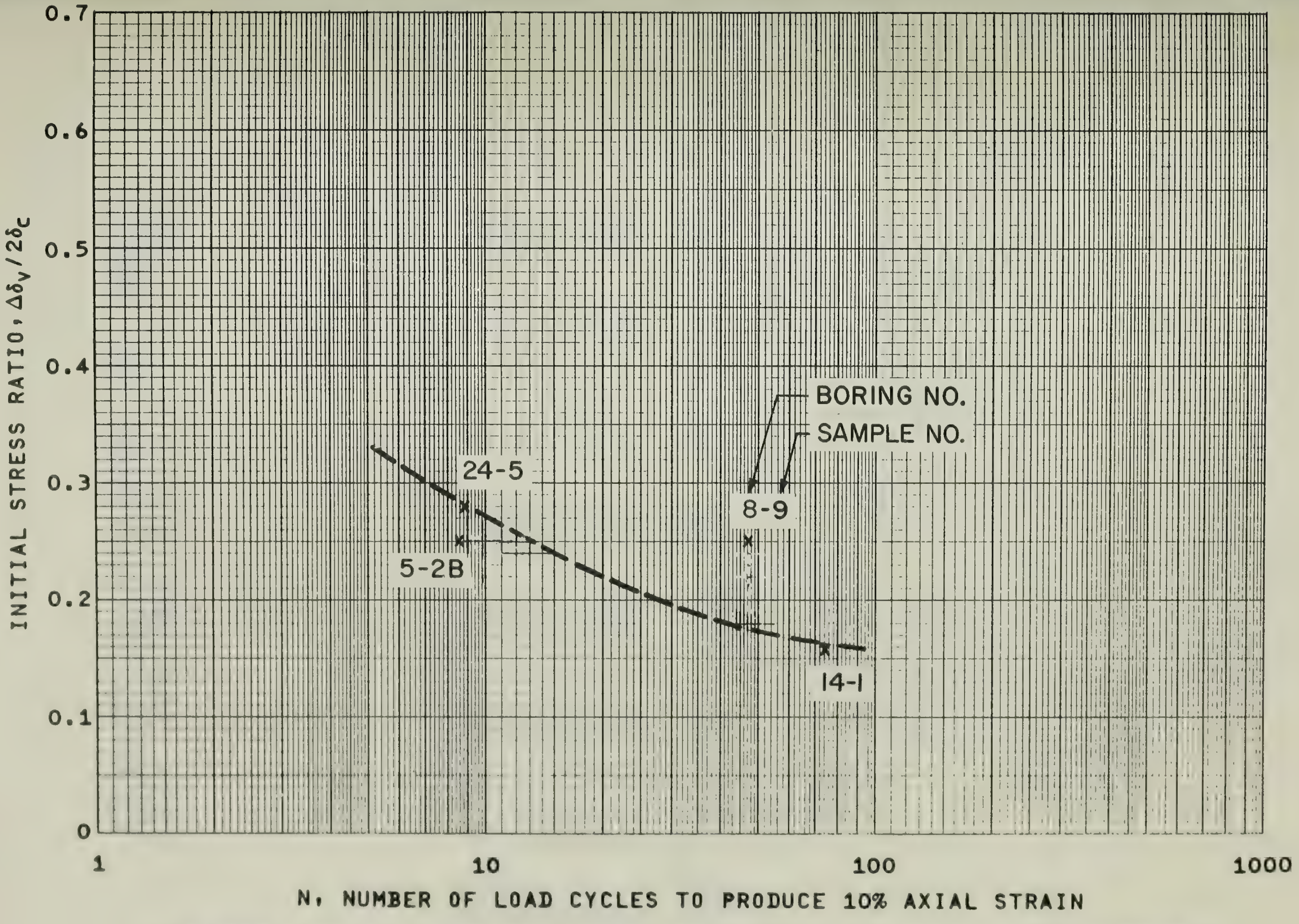
**DAMES & MOORE**



ATTENUATION RELATIONSHIP
FOR ROCK / VERY STIFF SOIL SITES

(FROM DONOVAN & BORNSTEIN, 1978)

DAMES & MOORE



# SUMMARY OF STRESS-CONTROLLED LIQUEFACTION TESTS ON DUNE SAND

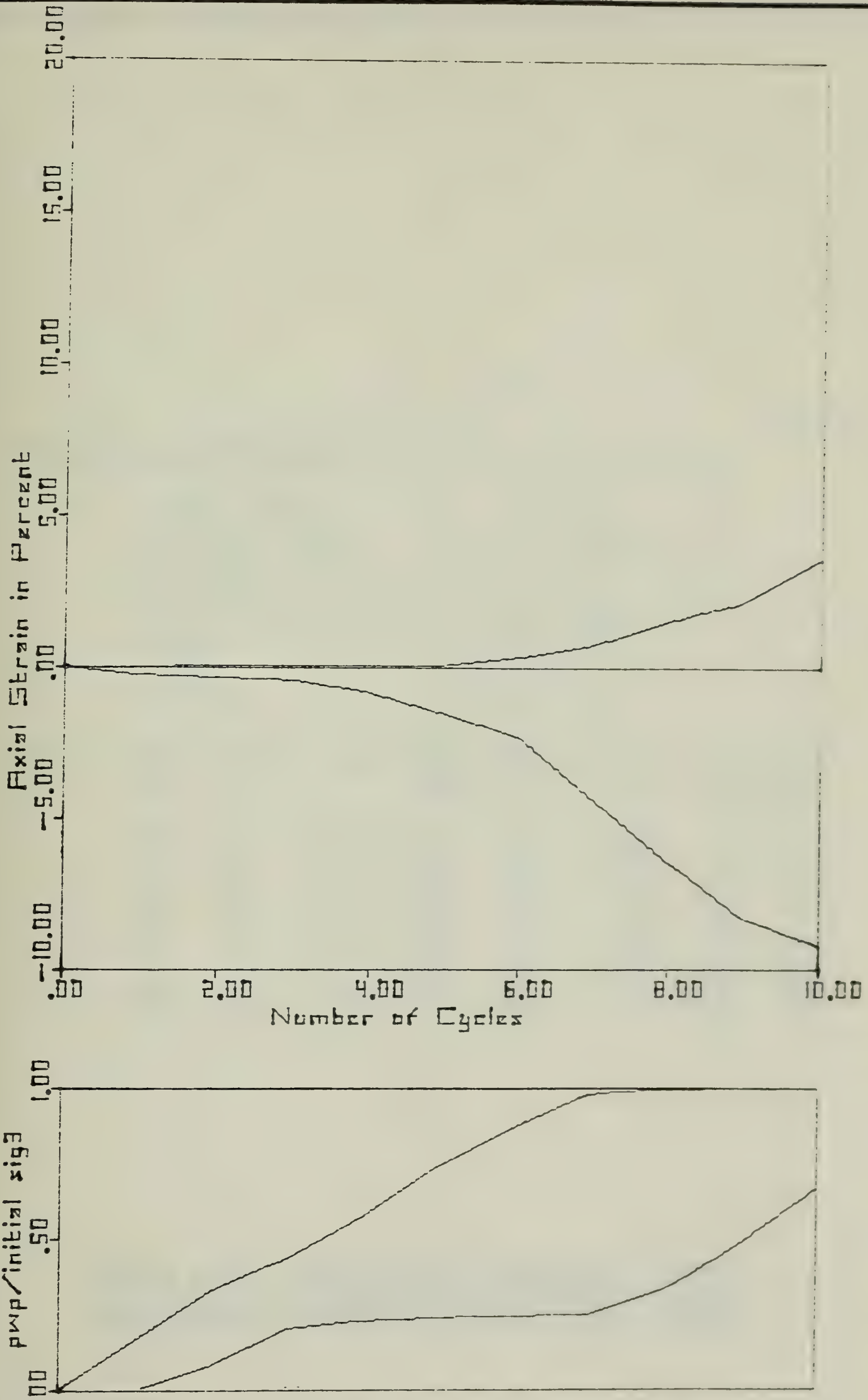
```
                                                                      21 NOV 7
CCSF 0185-131-03 BORING 24 SAMPLE 5 AT 20 FEET
  STRESS CONTROLLED LIQUEFACTION TEST ON BROWN FINE SAND

             SAMPLE HEIGHT                 =      5.00 IN
             SAMPLE DIAMETER               =      2.42 IN
             INITIAL DRY DENSITY           =    101.9  PCF
             MOISTURE CONTENT              =      5.6  PERCENT
             SATURATED                     =                    YES
             DRY DENSITY AFTER CONSOL=          103.5  PCF
             MOISTURE CONTENT              =     22.1  PERCENT
             SIG1                          =   2000.   PSF
             SIG3                          =   2000.   PSF
             KC                            =      1.00
             SIGMEAN                       =   2000.   PSF

 CYCLE      PORE      PWP/       CYCLIC SHEAR  STRESS         TAU/       AXIAL  STRAIN
  NO.       PORE      SIG3     COMP      TENS    CUM AVE    SIGMEAN      P-P     MEAN
            (PSF)                        (PSF)                           (PERCENT)

   1        333.       .17     583.     -551.     567.        .28         .32     -.12
   2        666.       .33     583.     -545.     565.        .28         .40     -.16
   3        883.       .44     583.     -545.     565.        .28         .48     -.20
   4       1166.       .58     583.     -545.     565.        .28         .88     -.40
   5       1499.       .75     583.     -545.     564.        .28        1.61     -.76
   6       1749.       .87     592.     -539.     565.        .28        2.69     -.98
   7       1966.       .98     608.     -539.     566.        .28        5.18    -1.83
   8       1999.      1.00     624.     -491.     565.        .28        8.03    -2.45
   9       1999.      1.00     608.     -390.     558.        .28       10.56    -3.07
  10       1999.      1.00     539.     -253.     541.        .27       12.84    -2.81
```

# RESULTS OF CYCLIC TRIAXIAL TEST
# BORING 24, SAMPLE 5 AT 20 FEET



Stress-Controlled Cyclic Triaxial Test

RESULTS OF CYCLIC TRIAXIAL TEST
BORING 24 SAMPLE 5 AT 20 FEET

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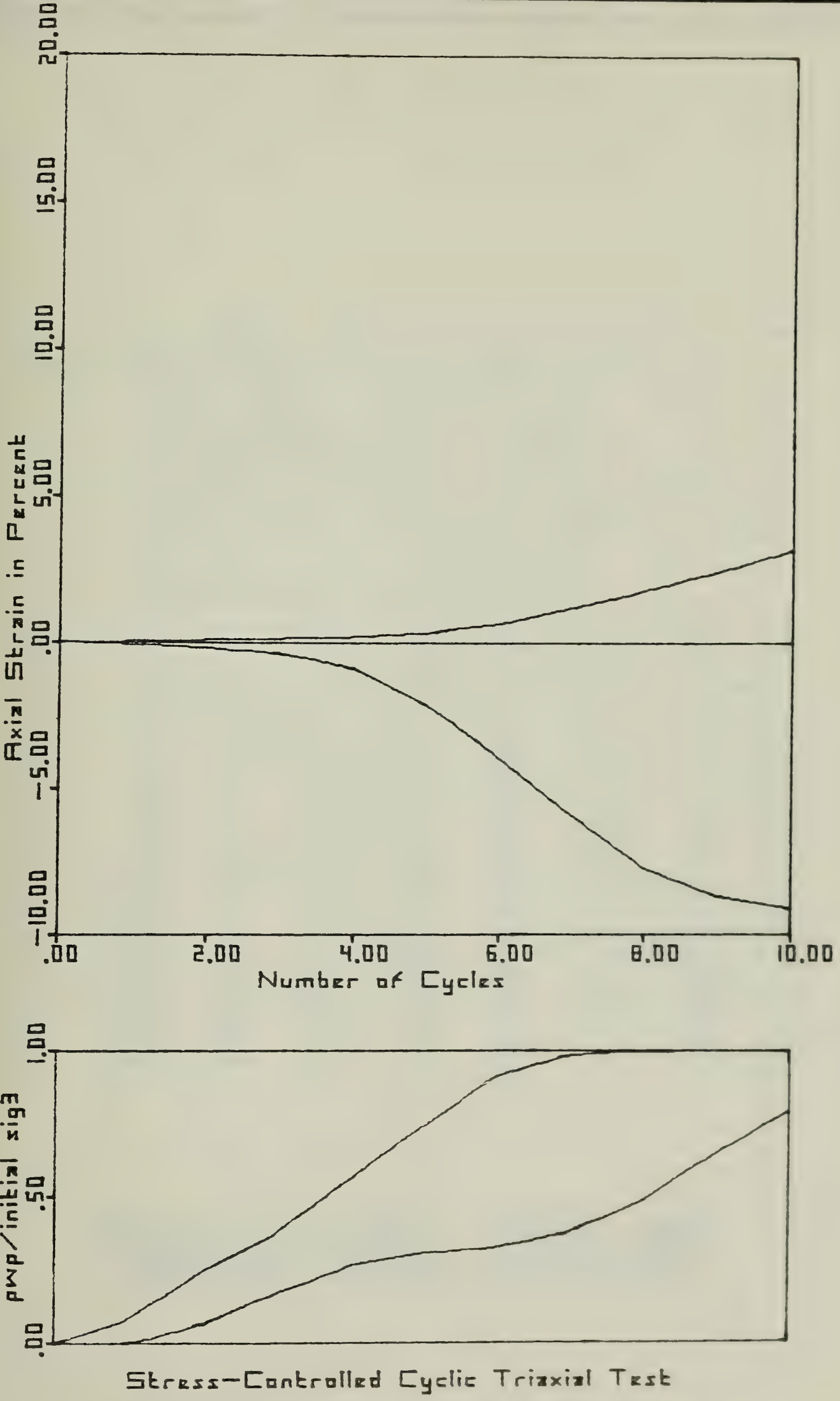
                                                                        16 NOV 78
CCSF 0185-131-03 BORING 5 SAMPLE 2B AT 19.6 FEET
  STRESS CONTROLLED LIQUEFACTION ON BROWN SAND (DUNE) VERY DRY

             SAMPLE HEIGHT             =      5.07 IN
             SAMPLE DIAMETER           =      2.41 IN
             INITIAL DRY DENSITY       =     98.7  PCF
             MOISTURE CONTENT          =       .6  PERCENT
             SATURATED                 =                          YES
             DRY DENSITY AFTER CONSOL=      100.2  PCF
             MOISTURE CONTENT          =     24.0  PERCENT
             SIG1                      =   2000.   PSF
             SIG3                      =   2000.   PSF
             KC                        =      1.00
             SIGMEAN                   =   2000.   PSF

 CYCLE     PORE     PWP/      CYCLIC SHEAR -STRESS       TAU/      AXIAL STRAIN
  NO.      PORE     SIG3    COMP     TENS   CUM AVE    SIGMEAN     P-P    MEAN
          (PSF)                     (PSF)                          (PERCENT)

   1       167.      .08    511.    -488.     500.       .25        .12    -.02
   2       500.      .25    511.    -488.     500.       .25        .28    -.06
   3       750.      .37    511.    -479.     498.       .25        .52    -.14
   4      1133.      .57    511.    -457.     494.       .25       1.07    -.38
   5      1499.      .75    511.    -463.     493.       .25       2.50    -.93
   6      1833.      .92    527.    -463.     493.       .25       4.64   -1.65
   7      1966.      .98    543.    -441.     493.       .25       7.14   -2.38
   8      1999.     1.00    527.    -367.     487.       .24       9.51   -2.97
   9      1999.     1.00    485.    -271.     475.       .24      11.14   -3.15
  10      1999.     1.00    415.    -192.     458.       .23      12.29   -2.97
```

# RESULTS OF CYCLIC TRIAXIAL TEST
# BORING 5, SAMPLE 2B AT 19.6 FEET



RESULTS OF CYCLIC TRIAXIAL TEST
BORING 5 SAMPLE 2B AT 19.6 FEET

DAMES & MOORE

PLATE D-6B

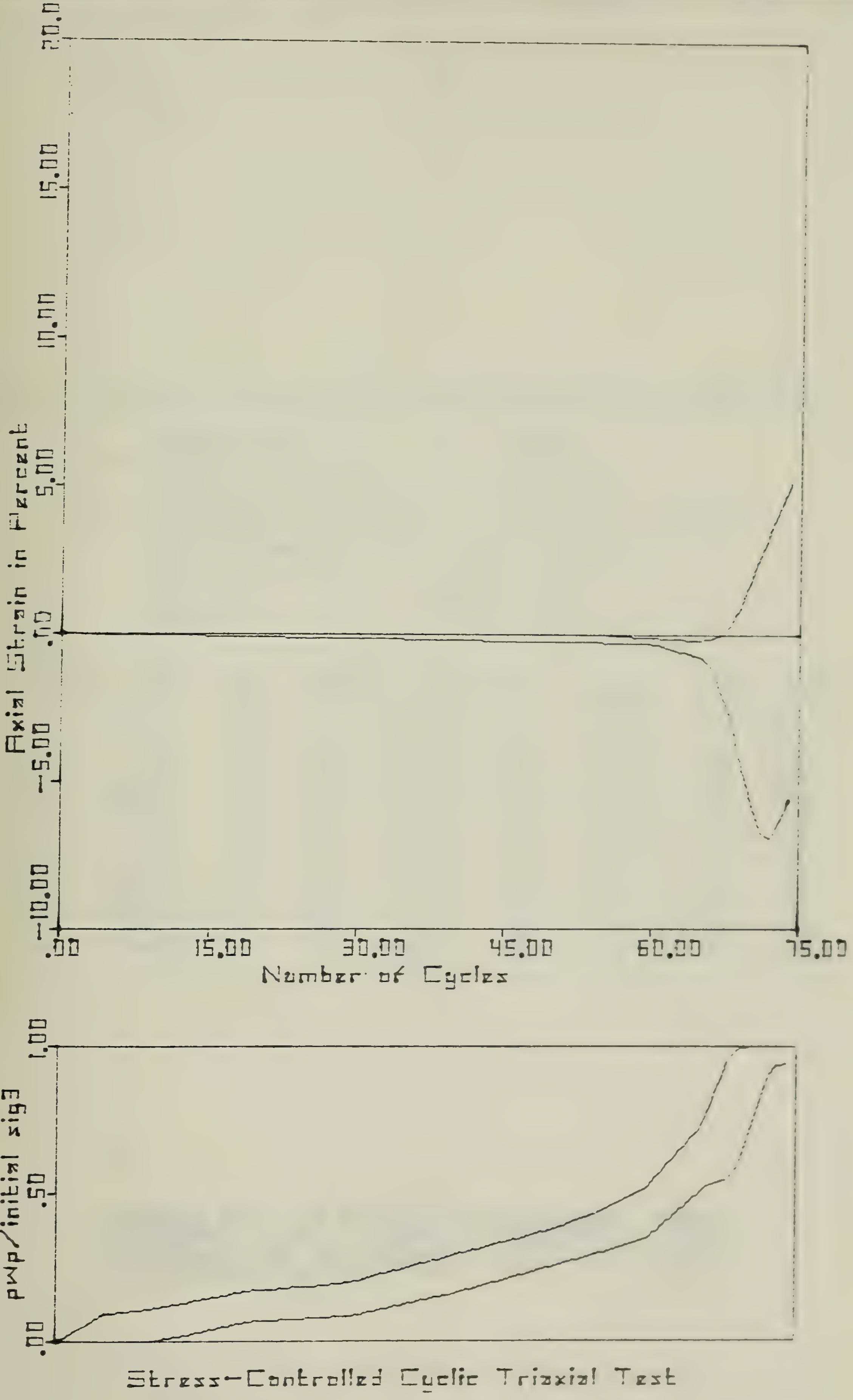
```
                                                                               21 NOV 7
CCSF 0185-131-03 BORING 14 SAMPLE 1 AT 21.4 FEET
  STRESS CONTROLLED LIQUEFACTION TEST ON BROWN FINE SAND

              SAMPLE HEIGHT                  =       5.08  IN
              SAMPLE DIAMETER                =       2.40  IN
              INITIAL DRY DENSITY            =      96.9   PCF
              MOISTURE CONTENT               =      16.2   PERCENT
              SATURATED                      =                           YES
              DRY DENSITY AFTER CONSOL=             98.0   PCF
              MOISTURE CONTENT               =      23.9   PERCENT
              SIG1                           =    2000.    PSF
              SIG3                           =    2000.    PSF
              KC                             =       1.00
              SIGMEAN                        =    2000.    PSF

  CYCLE     PORE      PWP/     CYCLIC SHEAR STRESS         TAU/      AXIAL STRAIN
   NO.      PORE      SIG3     COMP     TENS    CUM AVE   SIGMEAN     P-P    MEAN
            (PSF)                      (PSF)                           (PERCENT)

    1        17.      .01      328.    -316.     322.       .16        .04   -.02
    5       191.      .10      328.    -316.     322.       .16        .04   -.02
   10       226.      .11      328.    -316.     322.       .16        .08   -.04
   20       348.      .17      328.    -316.     322.       .16        .12   -.06
   30       400.      .20      328.    -316.     322.       .16        .16   -.08
   40       574.      .29      328.    -316.     322.       .16        .20   -.10
   50       748.      .37      328.    -316.     322.       .16        .24   -.12
   55       870.      .43      328.    -316.     322.       .16        .28   -.14
   60      1044.      .52      328.    -316.     322.       .16        .24   -.20
   65      1426.      .71      328.    -306.     322.       .16        .59   -.49
   66      1583.      .79      328.    -303.     321.       .16       1.11   -.63
   67      1740.      .87      338.    -299.     321.       .16       1.97   -.99
   68      1913.      .96      348.    -296.     321.       .16       3.36  -1.28
   69      1983.      .99      354.    -290.     321.       .16       5.41  -1.72
   70      2000.     1.00      357.    -232.     321.       .16       7.62  -1.92
   71      2000.     1.00      332.    -161.     320.       .16       9.44  -1.99
   72      2000.     1.00      290.     -93.     318.       .16      10.38  -1.72
   73      2000.     1.00      232.     -58.     316.       .16      10.66   -.99
   74      2000.     1.00      193.     -39.     313.       .16      10.78   -.22
```

# RESULTS OF CYCLIC TRIAXIAL TEST
# BORING 14, SAMPLE 1 AT 21.4 FEET



RESULTS OF CYCLIC TRIAXIAL TEST
BORING 14 SAMPLE 1 AT 21.4 FEET

DAMES & MOORE

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                                                                         21 NOV 78
CCSF 0185-131-03 BORING 14 SAMPLE 1 AT 21.4 FEET INCREASE GAIN BY HAND
   STRESS CONTROLLED LIQUEFACTION ON BROWN FINE SAND-RERUN,HIGHER STRESS

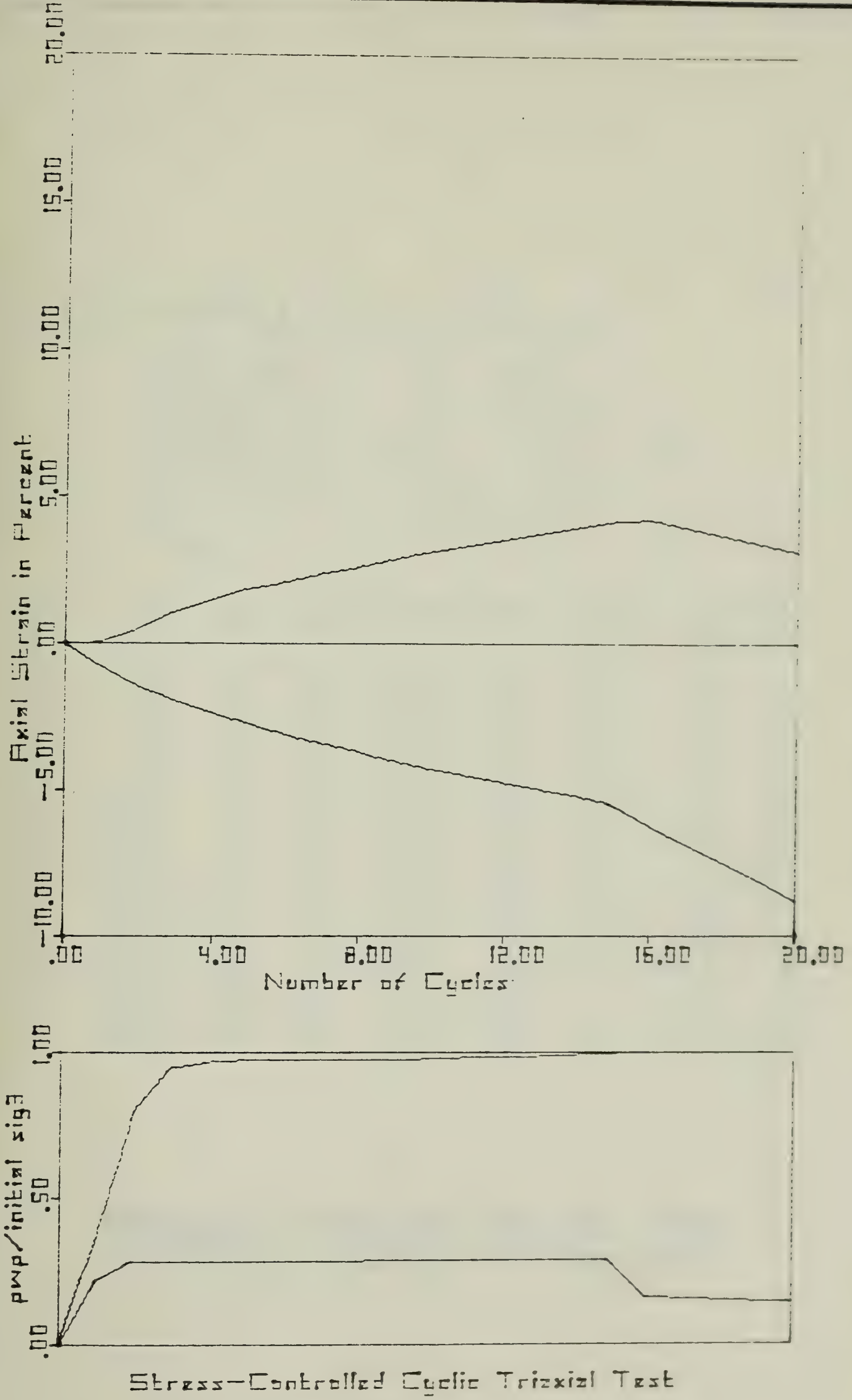
                SAMPLE HEIGHT                 =      5.08 IN
                SAMPLE DIAMETER               =      2.40 IN
                INITIAL DRY DENSITY           =     96.9  PCF
                MOISTURE CONTENT              =     16.2  PERCENT
                SATURATED                     =                      YES
                DRY DENSITY AFTER CONSOL=           98.0  PCF
                MOISTURE CONTENT              =     23.9  PERCENT
                SIG1                          =   2000.   PSF
                SIG3                          =   2000.   PSF
                KC                            =      1.00
                SIGMEAN                       =   2000.   PSF

  CYCLE     PORE      PWP/       CYCLIC SHEAR STRESS         TAU/       AXIAL STRAIN
   NO.      PORE      SIG3      COMP     TENS    CUM AVE    SIGMEAN      P-P    MEAN
           (PSF)                        (PSF)                           (PERCENT)

    1       735.       .37      325.    -470.     398.        .20         .87   -.39
    2      1598.       .80      325.    -486.     402.        .20        1.97   -.51
    3      1902.       .95      332.    -493.     405.        .20        3.12   -.45
    4      1934.       .97      348.    -499.     410.        .20        3.95   -.43
    5      1950.       .98      354.    -509.     414.        .21        4.70   -.45
    6      1950.       .98      361.    -515.     418.        .21        5.25   -.53
   10      1950.       .98      386.    -509.     430.        .21        7.50   -.59
   14      1982.       .99      386.    -483.     431.        .22        9.20   -.61
   15      1998.      1.00      386.    -483.     431.        .22        9.71   -.67
   16      1998.      1.00      364.    -489.     431.        .22       10.50   -.99
   20      1998.      1.00      322.    -493.     426.        .21       11.92  -2.84
```

## RESULTS OF CYCLIC TRIAXIAL TEST
## BORING 14, SAMPLE 1 AT 21.4 FEET

DAMES & MOORE



RESULTS OF CYCLIC TRIAXIAL TEST
BORING 14 SAMPLE 1 AT 21.4 FEET - RERUN

DAMES & MOORE

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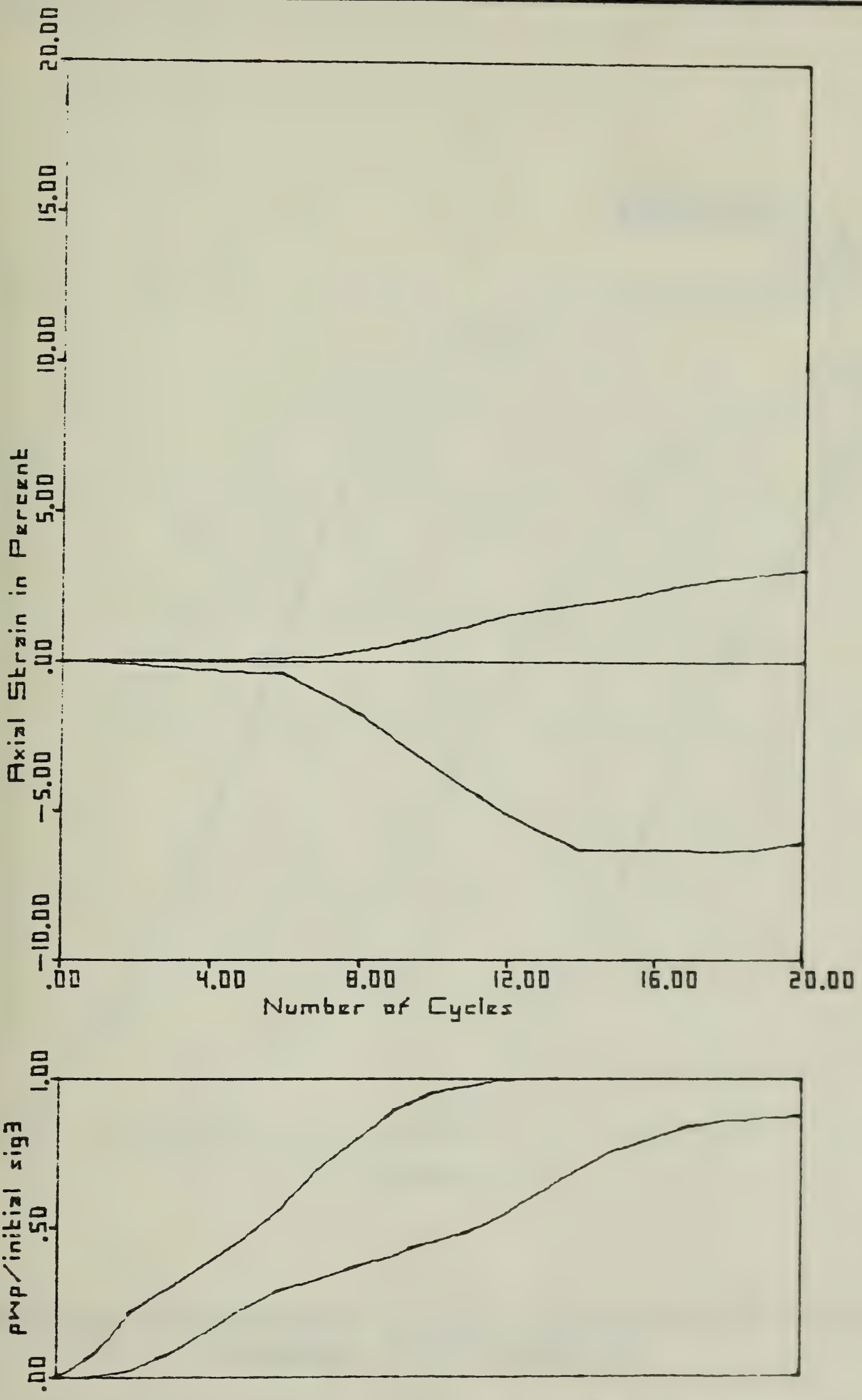
                                                                          16 NOV 78
CCSF 0185-131-03 BORING 8 SAMPLE 9 AT 19.5 FEET
  STRESS CONTROLLED LIQUEFACTION ON BROWN SAND (DUNE)

               SAMPLE HEIGHT               =      5.07 IN
               SAMPLE DIAMETER             =      2.40 IN
               INITIAL DRY DENSITY         =     96.5  PCF
               MOISTURE CONTENT            =      8.0  PERCENT
               SATURATED                   =                       YES
               DRY DENSITY AFTER CONSOL=         97.6  PCF
               MOISTURE CONTENT            =     26.4  PERCENT
               SIG1                        =   2000.   PSF
               SIG3                        =   2000.   PSF
               KC                          =      1.00
               SIGMEAN                     =   2000.   PSF

 CYCLE      PORE      PWP/       CYCLIC SHEAR-STRESS        TAU/       AXIAL STRAIN
  NO.       PORE      SIG3     COMP      TENS   CUM AVE   SIGMEAN      P-P    MEAN
           (PSF)                         (PSF)                          (PERCENT)

   1        156.       .08      487.     -513.     500.       .25        .08     .00
   2        453.       .23      487.     -513.     500.       .25        .20    -.02
   3        609.       .30      487.     -513.     500.       .25        .28    -.06
   4        766.       .38      487.     -506.     499.       .25        .40    -.12
   5        937.       .47      487.     -494.     497.       .25        .48    -.16
   6       1141.       .57      487.     -481.     495.       .25        .55    -.16
   7       1406.       .70      487.     -474.     493.       .25       1.27    -.48
   8       1609.       .80      487.     -455.     490.       .25       2.14    -.71
   9       1797.       .90      487.     -436.     487.       .24       3.29   -1.05
  10       1906.       .95      487.     -417.     484.       .24       4.48   -1.33
  11       1953.       .98      481.     -385.     479.       .24       5.62   -1.58
  12       2000.      1.00      449.     -336.     472.       .24       6.73   -1.78
  13       2000.      1.00      401.     -288.     462.       .23       7.52   -1.98
  14       2000.      1.00      356.     -250.     451.       .23       8.32   -2.18
  15       2000.      1.00      320.     -199.     438.       .22       8.51   -2.08
  16       2000.      1.00      266.     -170.     424.       .21       8.71   -1.98
  17       2000.      1.00      250.     -154.     411.       .21       9.03   -1.82
  18       2000.      1.00      224.     -128.     398.       .20       9.19   -1.74
  19       2000.      1.00      192.     -115.     385.       .19       9.23   -1.64
  20       2000.      1.00      176.     -103.     373.       .19       9.15   -1.49
```

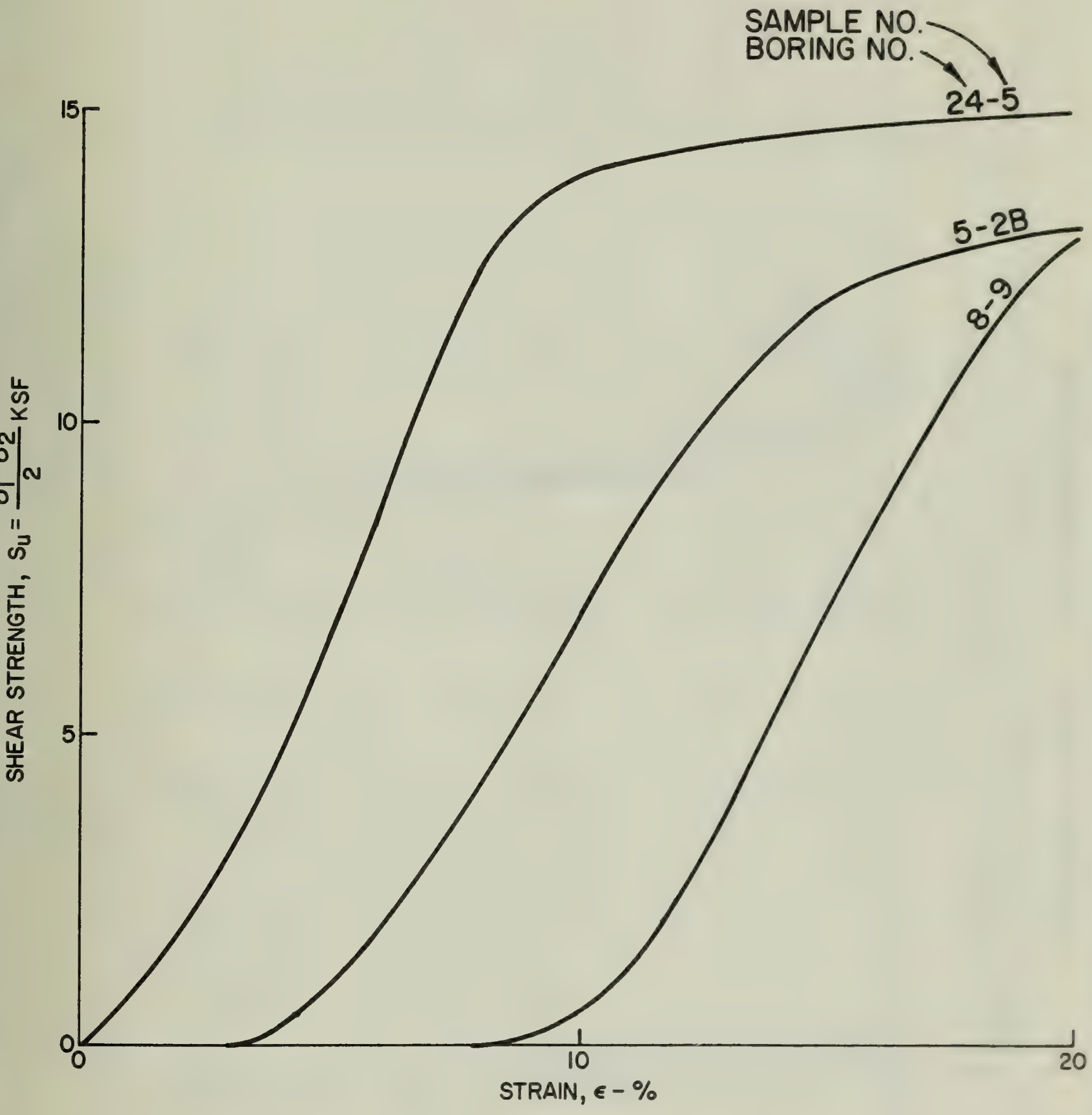
# RESULTS OF CYCLIC TRIAXIAL TEST
# BORING 8, SAMPLE 9 AT 19.5 FEET



Stress—Controlled Cyclic Triaxial Test

RESULTS OF CYCLIC TRIAXIAL TEST
BORING 8 SAMPLE 9 AT 19.5 FEET

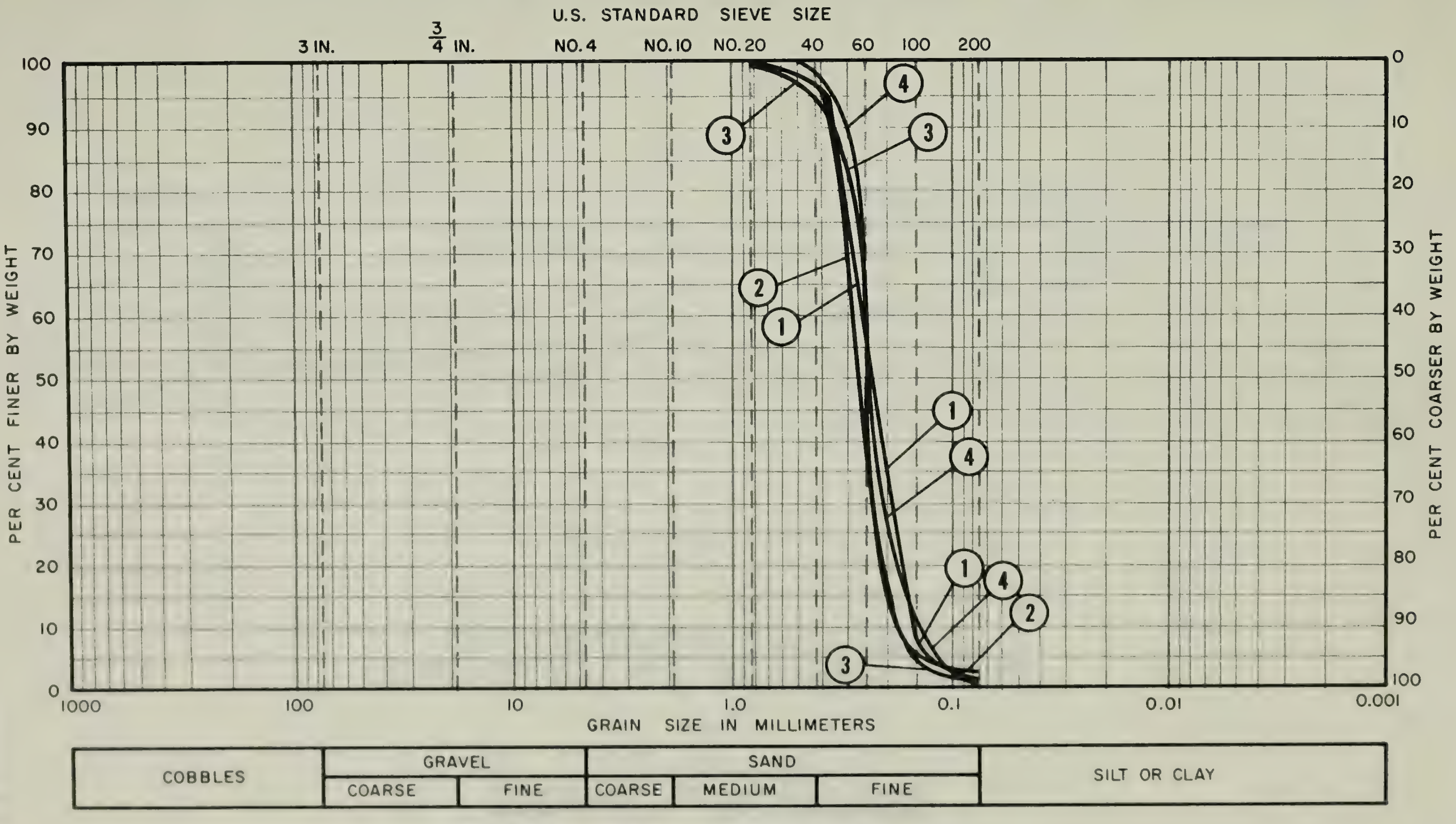
DAMES & MOORE



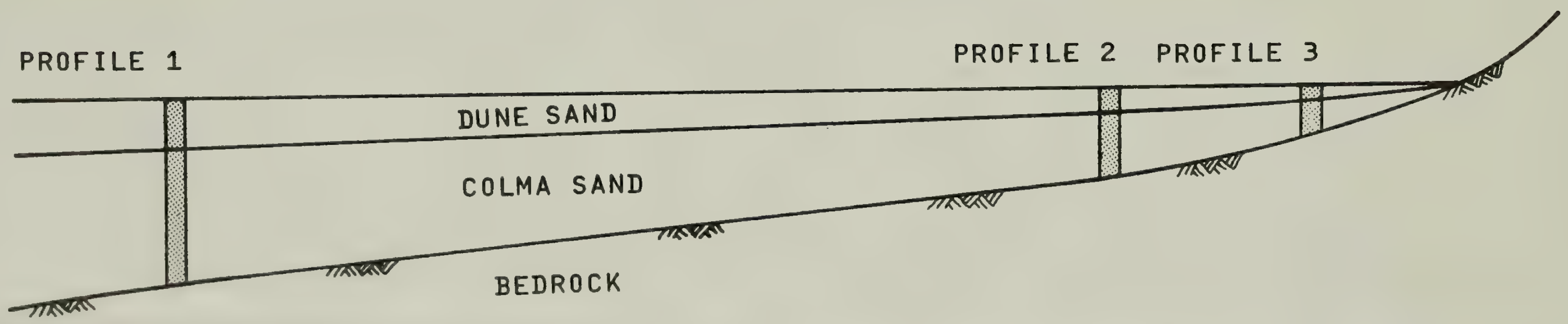
RESIDUAL STRENGTH OF STRESS - CONTROLLED CYCLIC TRIAXIAL TEST SAMPLES

DAMES & MOORE

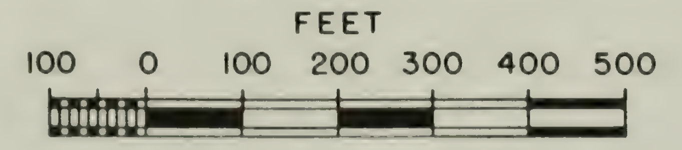
| BORING | DEPTH | ELEV. | SAMPLE | SOIL TYPE | PERM. CM/SEC | SYMBOL | SOIL CLASSIFICATION | KEY |
|---|---|---|---|---|---|---|---|---|
| 5 | 19.6 | +51 | 2 | DUNE | | SP | LIGHT BROWN FINE SAND | ① |
| 8 | 19.5 | +8 | 9 | DUNE | | SP | BROWN FINE SAND | ② |
| 14 | 21.4 | +90 | 1 | DUNE | | SP | BROWN FINE SAND | ③ |
| 24 | 20.0 | +65 | 5 | DUNE | | SP | BROWN FINE SAND | ④ |



# GRAIN-SIZE DISTRIBUTION
(unified soil classification system)



# REPRESENTATIVE SOIL PROFILES USED FOR THE SOIL RESPONSE ANALYSIS



ACCOPRESS®

| | |
|---|---|
| 25070 | YELLOW |
| 25071 | BLACK |
| 25072 | LIGHT BLUE |
| 25073 | DARK BLUE |
| 25074 | LIGHT GRAY |
| 25075 | LIGHT GREEN |
| 25076 | DARK GREEN |
| 25077 | TANGERINE |
| 25078 | RED |
| 25079 | EXECUTIVE RED |

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COVERS

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ACCO INTERNATIONAL INC
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